6-02 CONCRETE STRUCTURES

6-02.1 Description

This Work consists of the construction of all Structures (and their parts) made of Portland cement concrete with or without reinforcement, including bridge approach slabs. Any part of a Structure to be made of other materials shall be built as these Specifications require elsewhere.

6-02.2 Materials

Materials shall meet the requirements of the following sections:

Portland Cement	9-01
Aggregates for Portland Cement Concrete	9-03.1
Gravel Backfill	9-03.12
Joint and Crack Sealing Materials	9-04
Reinforcing Steel	9-07
Epoxy-Coated Reinforcing Steel	9-07
Prestressed Concrete Girders	9-19
Curing Materials and Admixtures	9-23
Fly Ash	9-23
Microsilica Fume	9-23.11
Plastic Waterstop	9-24
Water	9-25
Elastomeric Bearing Pads	9-31

6-02.3 Construction Requirements

6-02.3(1) Classification of Structural Concrete

The class of concrete to be used shall be as noted in the Plans and these Specifications. The numerical class of concrete defines the specified minimum compressive strength at 28-days in accordance with the WSDOT FOP for AASHTO T 22. The letter designation following the class of concrete identifies the specific use; P for Piling applications, W for Underwater applications, D for Deck applications, and A for Bridge Approach Slab applications.

The Contractor may request, in writing, permission to use a different class of concrete with either the same or a higher compressive strength than specified. The substitute concrete shall be evaluated for acceptance based on the specified class of concrete. The Engineer will respond in writing. The Contractor shall bear any added costs that result from the change.

6-02.3(2) Proportioning Materials

The total water soluble Chloride ion (Cl-) content of the mixed concrete shall not exceed 0.06-percent by weight of cementitious material for prestressed concrete nor 0.10-percent by weight of cementitious material for reinforced concrete. An initial evaluation may be obtained by testing individual concrete ingredients for total chloride ion content per AASHTO T 260 and totaling these to determine the total water soluble Chloride ion (Cl-) or the total water soluble Chloride ion (Cl-) in accordance with ASTM C 1218.

Unless otherwise specified, the Contractor shall use Type I or II Portland cement in all concrete as defined in Section 9-01.2(1).

The use of fly ash is required for Class 4000D and 4000P concrete, except that ground granulated blast furnace slag may be substituted for fly ash at a 1:1 ratio. The use of fly ash and ground granulated blast furnace slag is optional for all other classes of concrete.

Fly ash, if used, shall not exceed 35-percent by weight of the total cementitious material and shall conform to Section 9-23.9. Ground granulated blast furnace slag, if used, shall not exceed 25-percent by weight of the total cementitious material and shall conform to Section 9-23.10. When both ground granulated blast furnace slag and fly ash are included in the concrete mix, the total weight of both these materials is limited to 35-percent by weight of the total cementitious material.

The water/cement ratio shall be calculated on the total weight of cementitious material. The following are considered cementitious materials: Portland cement, fly ash, ground granulated blast furnace slag and microsilica.

As an alternative to the use of fly ash, ground granulated blast furnace slag and cement as separate components, a blended hydraulic cement that meets the requirements of Section 9-01.2(4) Blended Hydraulic Cements may be used.

6-02.3(2)A Contractor Mix Design

The Contractor shall provide a mix design in writing to the Engineer for all classes of concrete specified in the Plans except for those accepted based on a Certificate of Compliance. No concrete shall be placed until the Engineer has reviewed the mix design. The required average 28-day compressive strength shall be selected per ACI 318, Chapter 5, Section 5.3.2. ACI 211.1 and ACI 318 shall be used to determine proportions. The proposed mix for Class 4000P shall provide a minimum fly ash or ground granulated blast furnace slag content per cubic yard of 100-pounds, and a minimum cement content per cubic yard of 600-pounds. The proposed mix for Class 4000D shall provide a minimum fly ash or ground granulated blast furnace slag content per cubic yard of 75-pounds, and a minimum cement content per cubic yard of 660-pounds. All other concrete mix designs, except those for lean concrete and commercial concrete, shall have a minimum cementitious material content of 564-pounds per cubic yard of concrete.

The Contractor's submittal of a mix design shall be on WSDOT form 350-040 and shall provide a unique identification for each mix design and shall include the mix proportions per cubic yard, the proposed sources, the average 28-day compressive strength for which the mix is designed, the fineness modulus, and the water cement ratio. Concrete placeability, workability, and strength shall be the responsibility of the Contractor. The Contractor shall notify the Engineer in writing of any mix design modifications.

Fine aggregate shall conform to Section 9-03.1(2) Class 1 or Class 2.

Coarse aggregate shall conform to Section 9-03. An alternate combined aggregate gradation conforming to Section 9-03.1(5) may also be used. The nominal maximum size aggregate for Class 4000P shall be ½-inch. The nominal maximum size aggregate for Class 4000D shall be ¾-inch. The nominal maximum size aggregate for Class 4000A shall be 1-inch.

Nominal maximum size for concrete aggregate is defined as the smallest standard sieve opening through which the entire amount of the aggregate is permitted to pass.

Class 4000D and 4000P concrete shall include a water reducing admixture in the amount recommended by the manufacturer. A retarding admixture is required in concrete Class 4000P. Water reducing and retarding admixtures are optional for all other concrete classes.

A high-range water reducer (superplasticizer) may be used in all mix designs. Microsilica fume may be used in all mix designs. The use of a high-range water reducer or microsilica fume shall be submitted as a part of the Contractor's concrete mix design.

Air content shall be a minimum of 4.5-percent and a maximum of 7.5-percent for all concrete placed above the finished ground line.

6-02.3(2)B Commercial Concrete

Commercial concrete shall have a minimum compressive strength at 28-days of 3000-psi in accordance with WSDOT FOP for AASHTO T 22. Commercial concrete placed above the finished ground line shall be air entrained and have an air content from 4.5-percent to 7.5-percent per WAQTC FOP for AASHTO T 152. Commercial concrete does not require plant approval, mix design, or source approvals for cement, aggregate, and other admixtures.

Where concrete Class 3000 is specified for nonstructural items such as, culvert headwalls, plugging culverts, concrete pipe collars, pipe anchors, monument cases, luminaire bases, pedestals, cabinet bases, guardrail anchors, sign post foundations, fence post footings, sidewalks, curbs, and gutters, the Contractor may use commercial concrete. If commercial concrete is used for sidewalks, curbs, and gutters, it shall have a minimum cementitious material content of 564-pounds per cubic yard of concrete, shall be air entrained, and the tolerances of Section 6-02.3(5)C shall apply. Commercial concrete shall not be used for structural items such as, bridges, retaining walls, box culverts, or foundations for high mast luminaires, mast arm traffic signals, cantilever signs, and sign bridges. The Engineer may approve other nonstructural items not listed for use as commercial concrete.

6-02.3(2)C Vacant

6-02.3(2)D Lean Concrete

Lean concrete shall contain between 145 and 200-pounds of cement per cubic yard and have a maximum water/cement ratio of 2.

6-02.3(3) Admixtures

Concrete admixtures shall be added to the concrete mix at the time of batching the concrete or in accordance with the manufacturer's written procedure and as approved by the Engineer. A copy of the manufacturer's written procedure shall be furnished to the Engineer prior to use of any admixture. Any deviations from the manufacturer's written procedures shall be submitted to the Engineer for approval. Admixtures shall not be added to the concrete with the modified procedures until the Engineer has approved them in writing.

When the Contractor is proposing to use admixtures from different admixture manufacturers they shall provide evidence to the Engineer that the admixture will be compatible and not adversely effect the air void system of the hardened concrete. Test results complying with ASTM C 457 shall be provided as the evidence to satisfy this requirement. Admixture combinations which have been previously tested and which are in compliance with ASTM C 457 shall be listed in the Qualified Products List (QPL). Proposed combinations not found in the QPL shall meet this requirement.

Accelerators shall not be used.

Air entrained cement shall not be used to air entrain concrete.

6-02.3(4) Ready-Mix Concrete

All concrete, except commercial concrete and lean concrete shall be batched in a prequalified manual, semi-automatic, or automatic plant as described in Section 6-02.3(4)A. The Engineer is not responsible for any delays to the Contractor due to problems in getting the plant certified.

6-02.3(4)A Qualification of Concrete Suppliers

Batch Plant Prequalification may be obtained through one of the following methods:

1. Certification by the National Ready Mix Concrete Association (NRMCA). Information concerning NRMCA certification may be obtained from the NRMCA at 900 Spring Street, Silver Springs, MD 20910 or online at www.nrmca.org. The NRMCA certification shall be good for a 2-year period. When this method of certification is used the following documentation shall be submitted to the Project Engineer.
    a. A copy of the current NRMCA Certificate of Conformance, the concrete mix design(s) (WSDOT Form 350-040), along with copies of the truck list, batch plant scale certification, admixture dispensing certification, and volumetric water batching devices (including water meters) verification.
2. Independent evaluation certified by a Professional Engineer using NRMCA checklist. The Professional Engineer shall be licensed under title 18 RCW, state of Washington, qualified in civil engineering. The independent certification using the NRMCA checklist shall be good for a 2-year period. When this method of certification is used the following documentation shall be submitted to the Engineer.
    a. A copy of the Professional Engineer’s stamped and sealed NRMCA Verification of Inspection and Application for Certificate page from the NRMCA checklist, the concrete mix design(s) (WSDOT Form 350-040), along with copies of the truck list, batch plant scale certification, admixture dispensing certification, and volumetric water batching devices (including water meters) verification.
3. Inspection conducted by the Plant Manager, defined as the person directly responsible for the daily plant operation, using the NRMCA Plant Certification checklist. The Plant Manager certification shall be done prior to the start of a project, and every 6-months throughout the life of the project, and meet the following requirements:
    a. The Agreement to Regularly Check Scales and Volumetric Batching Dispensers page in the NRMCA Plant Certification checklist shall be signed by the Plant Manager and notarized.

b. The signed and notarized Agreement to Regularly Check Scales and Volumetric Batching Dispensers page and a copy of the NRMCA Plant Certification checklist cover page showing the plant designation, address and Company operating plant shall all be submitted to the Project Engineer with the concrete mix design (WSDOT Form 350-040), along with copies of the truck list, batch plant scale certification, admixture dispensing certification, and volumetric water batching devices (including water meters) verification.

c. The NRMCA Plant Certification checklists shall be maintained by the Plant Manager and are subject to review at any time by the Contracting Agency.

d. Volumetric water batching devices (including water meters) shall be verified every 90-days.

For central-mixed concrete, the mixer shall be equipped with a timer that prevents the batch from discharging until the batch has been mixed for the prescribed mixing time. A mixing time of 1 minute will be required after all materials and water have been introduced into the drum. Shorter mixing time may be allowed if the mixer performance is tested in accordance with (AASHTO M 157 Annex A1 Concrete Uniformity Requirements). Tests shall be conducted by an independent testing lab or by a commercial concrete producer's lab. If the tests are performed by a producer's lab, the Engineer or a representative will witness all testing.

For shrink-mixed concrete, the mixing time in the stationary mixer shall not be less than 30-seconds or until the ingredients have been thoroughly blended.

For transit-mixed or shrink-mixed concrete, the mixing time in the transit mixer shall be a minimum of 70-revolutions at the mixing speed designated by the manufacturer of the mixer. Following mixing, the concrete in the transit mixer may be agitated at the manufacturer's designated agitation speed. A maximum of 320-revolutions (total of mixing and agitation) will be permitted prior to discharge.

All transit-mixers shall be equipped with an operational revolution counter and a functional device for measurement of water added. All mixing drums shall be free of concrete buildup and the mixing blades shall meet the minimum Specifications of the drum manufacturer. A copy of the manufacturer's blade dimensions and configuration shall be on file at the concrete producer's office. A clearly visible metal data plate (or plates) attached to each mixer and agitator shall display: (1) the maximum concrete capacity of the drum or container for mixing and agitating, and (2) the rotation speed of the drum or blades for both the agitation and mixing speeds. Mixers and agitators shall always operate within the capacity and speed-of-rotation limits set by the manufacturer. Any mixer, when fully loaded, shall keep the concrete uniformly mixed. All mixers and agitators shall be capable of discharging the concrete at a steady rate. Only those transit-mixers which meet the above requirements will be allowed to deliver concrete to any Contracting Agency project covered by these Specifications.

In transit-mixing, mixing shall begin within 30-seconds after the cement is added to the aggregates.

Central-mixed concrete, transported by truck mixer/agitator, shall not undergo more than 250-revolutions of the drum or blades before beginning discharging. To remain below this limit, the suppler may agitate the concrete intermittently within the prescribed time limit. When water or admixtures are added after the load is initially mixed, an additional 30-revolutions will be required at the recommended mixing speed.

For each project, at least biannually, or as required, the Plant Manager will examine mixers and agitators to check for any buildup of hardened concrete or worn blades. If this examination reveals a problem, or if the Engineer wishes to test the quality of the concrete, slump tests may be performed with samples taken at approximately the ¼ and ¾ points as the batch is discharged. The maximum allowable slump difference shall be as follows:

If the average of the 2 slump tests is ≤ 4-inches, the difference shall be ≤ 1-inch or if the average of the 2 slump tests is >4-inches, the difference shall be ≤ 1½-inches.

If the slump difference exceeds these limits, the equipment shall not be used until the faulty condition is corrected. However, the equipment may continue in use if longer mixing times or smaller loads produce batches that pass the slump uniformity tests.

All concrete production facilities will be subject to verification inspections at the discretion of the Engineer. Verification inspections are a check for: current scale certifications; accuracy of water metering devices; accuracy of the batching process; and verification of coarse aggregate quality.

If the concrete producer fails to pass the verification inspection, the following actions will be taken:

1. For the first violation, a written warning will be provided.
2. For the second violation, the Engineer will give written notification and the Contracting Agency will assess a price reduction equal to 15-percent of the invoice cost of the concrete that is supplied from the time of the infraction until the deficient condition is corrected.
3. For the third violation, the concrete supplier is suspended from providing concrete until all such deficiencies causing the violation have been permanently corrected and the plant and equipment have been reinspected and meets all the prequalification requirements.
4. For the fourth violation, the concrete supplier shall be disqualified from supplying concrete for 1-year from the date of disqualification. At the end of the suspension period the concrete supplier may request that the facilities be inspected for prequalification.

6-02.3(4)B Jobsite Mixing

For small quantities of concrete, the Contractor may mix concrete on the job site provided the Contractor has requested in writing and received written permission from the Engineer. The Contractor's written request shall include a mix design, batching and mixing procedures, and a list of the equipment performing the job-site mixing. All job site mixed concrete shall be mixed in a mechanical mixer.

If the Engineer permits, hand mixing of concrete will be permitted for pipe collars, pipe plugs, fence posts, or other items approved by the Engineer, provided the hand mixing is done on a watertight platform in a way that distributes materials evenly throughout the mass. Mixing shall continue long enough to produce a uniform mixture. No hand mixed batch shall exceed ½-cubic yard.

Concrete mixed at the jobsite is never permitted for placement in water.

6-02.3(4)C Consistency

The maximum slump for concrete shall be:

1. 3.5-inches for vibrated concrete placed in all bridge roadway slabs, bridge approach slabs, and flat slab bridge Superstructures.
2. 4.5-inches for all other vibrated concrete.
3. 7-inches for non-vibrated concrete. (Includes Class 4000P)
4. 9-inches for shafts when using Class 4000P, provided the water cement ratio does not exceed 0.44 and a water reducer is used meeting the requirements of 9-23.6.
5. 5.5-inches for all concrete placed in curbs, gutters, and sidewalks.

When a high range water reducer is used, the maximum slump listed in 1, 2, 3, and 5 above, may be increased an additional 2-inches.

6-02.3(4)D Temperature and Time For Placement

Concrete temperatures shall remain between 55°F and 90°F while it is being placed. Precast concrete that is heat cured per Section 6-02.3(25)D shall remain between 50°F and 90°F while being placed. The batch of concrete shall be discharged at the project site no more than 1½-hours after the cement is added to the concrete mixture. The time to discharge may be extended to 1¾-hours if the temperature of the concrete being placed is less than 75°F. With the approval of the Engineer and as long as the temperature of the concrete being placed is below 75°F, the maximum time to discharge may be extended to two-hours. When conditions are such that the concrete may experience an accelerated initial set, the Engineer may require a shorter time to discharge. The time to discharge may be extended upon written request from the Contractor. This time extension will be considered on a case by case basis and requires the use of specific retardation admixtures and the approval of the Engineer.

6-02.3(5) Acceptance of Concrete

6-02.3(5)A General

Lean concrete and commercial concrete will be accepted based on a Certificate of Compliance to be provided by the supplier as described in Section 6-02.3(5)B.

All other concrete will be accepted based on conformance to the requirement for temperature, slump, air content for concrete placed above finished ground line, and the specified compressive strength at 28-days for sublots as tested and determined by the Contracting Agency.

A sublot is defined as the material represented by an individual strength test. An individual strength test is the average compressive strength of cylinders from the same sample of material.

Each sublot will be deemed to have met the specified compressive strength requirement when both of the following conditions are met:

1. Individual strength tests do not fall below the specified strength by more than 12½-percent or 500-psi, whichever is least.
2. An individual strength test averaged with the 2 preceding individual strength tests meets or exceeds specified strength (for the same class and exact mix I.D. of concrete on the same Contract).

When compressive strengths fail to satisfy one or both of the above requirements, the Contractor may:

1. Request acceptance based on the Contractor/Suppliers strength test data for cylinders made from the same truckload of concrete as the Contracting Agency cylinders; provided:
    a. The Contractor's test results are obtained from testing cylinders fabricated, handled, and stored for 28-days in accordance with WSDOT FOP for AASHTO T 23 and tested in accordance with AASHTO T 22. The test cylinders shall be the same size cylinders as those cast by the Contracting Agency.
    b. The technician fabricating the cylinders is qualified by either ACI, Grade 1 or WAQTC to perform this Work.
    c. The Laboratory performing the tests per AASHTO T 22 has an equipment calibration/certification system, and a technician training and evaluation process per AASHTO R-18.
    d. Both the Contractor and Contracting Agency have at least 15 test results from the same mix to compare. The Contractor's results could be used if the Contractor's computed average of all their test results is within 1 standard deviation of the Contracting Agency's average test result. The computed standard deviation of the Contractor's results must also be within plus or minus 200-psi of the Contracting Agency's standard deviation.
2. Request acceptance of in-place concrete strength based on core results. This method will not be used if the Engineer determines coring would be harmful to the integrity of the Structure. Cores, if allowed, will be obtained by the Contractor in accordance with AASHTO T 24 and delivered to the Contracting Agency for testing in accordance with AASHTO T 22. If the concrete in the Structure will be dry under service conditions, the core will be air dried at a temperature of between 60°F and 80°F and at a relative humidity of less than 60-percent for 7-days before testing, and will be tested air dry.

Acceptance for each sublot by the core method requires that the average compressive strength of 3 cores be at least 85-percent of the specified strength with no 1 core less than 75-percent of the specified strength. When the Contractor requests strength analysis by coring, the results obtained will be accepted by both parties as conclusive and supersede all other strength data for the concrete sublot.

If the Contractor elects to core, cores shall be obtained no later than 50-days after initial concrete placement. The Engineer will concur in the locations to be cored. Repair of cored areas shall be the responsibility of the Contractor. The cost incurred in coring and testing these cores, including repair of core locations, shall be borne by the Contractor.

6-02.3(5)B Certification of Compliance

The concrete producer shall provide a Certificate of Compliance for each truckload of concrete. The Certificate of Compliance shall verify that the delivered concrete is in compliance with the mix design and shall include:

Manufacturer plant (batching facility)
Contracting Agency Contract number.
Date
Time batched
Truck No.
Initial revolution counter reading
Quantity (quantity batched this load)
Type of concrete by class and producer design mix number
Cement producer, type, and Mill Certification No. (The mill test number as required by Section 9-01.3 is the basis for acceptance of cement.)
Fly ash (if used) brand and Type
Approved aggregate gradation designation

Mix design weight per cubic yard and actual batched weights for:
Cement
Fly ash (if used)
Coarse concrete aggregate and moisture content (each size)
Fine concrete aggregate and moisture content
Water (including free moisture in aggregates)
Admixtures brand and total quantity batched
Air-entraining admixture
Water reducing admixture
Other admixture

For concretes that use combined aggregate gradation, the Certificate of Compliance shall include the aggregate components and moisture contents for each size in lieu of the aggregate information described above.

The Certificate of Compliance shall be signed by a responsible representative of the concrete producer, affirming the accuracy of the information provided. In lieu of providing a machine produced record containing all of the above information, the concrete producer may use the Contracting Agency-provided printed forms, which shall be completed for each load of concrete delivered to the project.

For commercial concrete, the Certificate of Compliance shall include, as a minimum, the batching facility, date, and quantity batched per load.

6-02.3(5)C Conformance to Mix Design

Cement, coarse and fine aggregate weights shall be within the following tolerances of the mix design:

Batch Volumes less than or equal to 4-cubic yards		
Cement	+5%	-1%
Aggregate	+10%	-2%
Batch Volumes more than 4-cubic yards		
Cement	+5%	-1%
Aggregate	+2%	-2%

If the total cementitious material weight is made up of different components, these component weights shall be within the following tolerances:

1. Portland cement weight plus 5-percent or minus 1-percent of that specified in the mix design.
2. Fly ash and ground granulated blast furnace slag weight plus or minus 5-percent of that specified in the mix design.
3. Microsilica weight plus or minus 10-percent of that specified in the mix design.

Water shall not exceed the maximum water specified in the mix design.

6-02.3(5)D Test Methods

Acceptance testing will be performed by the Contracting Agency in accordance with the WSDOT Materials Manual. The test methods to be used with this Specification are:

WSDOT FOP for AASHTO T 22	Compressive Strength of Cylindrical Concrete Specimens
WSDOT FOP for AASHTO T 23	Making and Curing Concrete Test Specimens in the Field
WSDOT FOP for AASHTO T 119	Slump of Hydraulic Cement Concrete
FOP for WAQTC TM 2	Sampling Freshly Mixed Concrete
WAQTC FOP for AASHTO T 152	Air Content of Freshly Mixed Concrete by the Pressure Method
WSDOT FOP for AASHTO T 231	Capping Cylindrical Concrete Specimens
WSDOT FOP for AASHTO T 309	Temperature of Freshly Mixed Portland Cement Concrete

6-02.3(5)E Point of Acceptance

Determination of concrete properties for acceptance will be made based on samples taken as follows:

Bridge decks, overlays, and barriers at the discharge of the placement system.

All other placements at the truck discharge.

It shall be the Contractor's responsibility to provide adequate and representative samples of the fresh concrete to a location designated by the Engineer for the testing of concrete properties and making of cylinder specimens. Samples shall be provided as directed in Sections 1-06.1 and 1-06.2. Once the Contractor has turned over the concrete for acceptance testing, no more mix adjustment will be allowed. The concrete will either be accepted or rejected.

6-02.3(5)F Water/Cement Ratio Conformance

The actual water cement ratio shall be determined from the certified proportions of the mix, adjusting for on the job additions. No water may be added after acceptance testing or after placement has begun, except for concrete used in slip forming. For slip-formed concrete, water may be added during placement but shall not exceed the maximum water cement ratio in the mix design, and shall meet the requirements for consistency as described in Section 6-02.3(4)C. If water is added, an air and temperature test shall be taken prior to resuming placement to ensure that Specification conformance has been maintained.

6-02.3(5)G Sampling and Testing Frequency for Temperature, Consistency, and Air Content

Concrete properties shall be determined from concrete as delivered to the project and as accepted by the Contractor for placement. The Contracting Agency will test for acceptance of concrete for slump, temperature, and air content, if applicable, as follows:

Sampling and testing will be performed before concrete placement from the first truck load. Concrete shall not be placed until tests for slump, temperature, and entrained air (if applicable) have been completed by the Engineer, and the results indicate that the concrete is within acceptable limits. Except for the first load of concrete, up to ½-cubic yard may be placed prior to testing for acceptance. Sampling and testing will continue for each load until 2 successive loads meet all applicable acceptance test requirements. After 2 successive tests indicate that the concrete is within specified limits, the sampling and testing frequency may decrease to 1 for every 5 truck loads. Loads to be sampled will be selected in accordance with the random selection process as outlined in WAQTC FOP for TM 2.

When the results for any subsequent acceptance test indicates that the concrete as delivered and approved by the Contractor for placement does not conform to the specified limits, the sampling and testing frequency will be resumed for each truck load. Whenever 2 successive subsequent tests indicate that the concrete is within the specified limits, the random sampling and testing frequency of 1 for every 5 truck loads may resume.

Sampling and testing for a placement of one class of concrete consisting of 50-cubic yards or less will be as listed above, except:

Sampling and testing will continue until 1 load meets all of the applicable acceptance requirements, and

After 1 set of tests indicate that the concrete is within specified limits, the remaining concrete to be placed may be accepted by visual inspection.

6-02.3(5)H Sampling and Testing for Compressive Strength and Initial Curing

Acceptance testing for compressive strength shall be conducted at the same frequency as the acceptance tests for temperature, consistency, and air content.

The Contractor shall provide, and maintain cure boxes for curing concrete cylinders. The Contractor shall also provide, maintain and operate all necessary power sources and connections needed to operate the curing box. Concrete cylinders shall be cured in a cure box in accordance with WSDOT FOP for AASHTO T 23. The cure boxes shall maintain a temperature between 60°F and 80°F for concrete with specified strengths less than 6000-psi and between 68°F and 78°F for concrete with specified strengths of 6000-psi and higher. A minimum/maximum thermometer shall be installed to measure the internal temperature of the cure box. The thermometer shall be readable from outside of the box and be capable of recording the high and low temperatures in a 24-hour period. The cure boxes shall create an environment that prevents moisture loss from the concrete specimens. The top shall have a working lock and the interior shall be rustproof. A moisture-proof seal shall be provided between the lid and the box. The cure box shall be the appropriate size to accommodate the number of concrete acceptance cylinders necessary or the Contractor shall provide additional cure boxes. Once concrete cylinders are placed in the cure box, the cure box shall not be moved until the cylinders have been cured in accordance with these Specifications. When concrete is placed at more than 1 location simultaneously, multiple cure boxes shall be provided.

The Contractor shall protect concrete cylinders in cure boxes from excessive vibration and shock waves during the curing period in accordance with Section 6-02.3(6)D.

6-02.3(5)I Vacant

6-02.3(5)J Vacant

6-02.3(5)K Rejecting Concrete

Rejection Without Testing — The Engineer, prior to sampling, may reject any batch or load of concrete that appears defective in composition; such as cement content or aggregate proportions. Rejected material shall not be incorporated in the Structure.

6-02.3(5)L Concrete With Non-Conforming Strength

Concrete with cylinder compressive strengths (fc) that fail to meet acceptance level requirements shall be evaluated for structural adequacy. If the material is found to be adequate, payment shall be adjusted in accordance with the following formula:

$$\text{Pay adjustment} = \frac{2(f'c - fc)(UP)(Q)}{f'c}$$

where	f′c	=	Specified minimum compressive strength at 28-days.
	fc	=	Compressive strength at 28-days as determined by AASHTO Test Methods.
	UP	=	Unit Contract price per cubic yard for the class of concrete involved.
	Q	=	Quantity of concrete represented by an acceptance test based on the required frequency of testing.

Concrete that fails to meet minimum acceptance levels using the coring method will be evaluated for structural adequacy. If the material is found to be adequate, payment shall be adjusted in accordance with the following formula:

$$\text{Pay adjustment} = \frac{3.56(.85f'c - f\ cores)(UP)(Q)}{f'c}$$

where	f’c	=	Specified minimum compressive strength at 28-days.
	f cores	=	Compressive strength of the cores as determined by AASHTO T-22.
	UP	=	Unit Contract price per cubic yard for the class of concrete involved.
	Q	=	Quantity of concrete represented by an acceptance test based on the required frequency of testing.

Where these Specifications designate payment for the concrete on other than a per cubic yard basis, the unit Contract price of concrete shall be taken as $300 per cubic yard for concrete Class 4000, 5000, and 6000. For concrete Class 3000, the unit contract price for Concrete shall be $160 per cubic yard.

6-02.3(6) Placing Concrete

The Contractor shall not place concrete:

1. On frozen or ice-coated ground or Subgrade;
2. Against or on ice-coated forms, reinforcing steel, structural steel, conduits, precast members, or construction joints;
3. Under rainy conditions; placing of concrete shall be stopped before the quantity of surface water is sufficient to affect or damage surface mortar quality or cause a flow or wash the concrete surface;
4. In any foundation until the Engineer has approved its depth and character;
5. In any form until the Engineer has approved it and the placement of any reinforcing in it; or
6. In any Work area when vibrations from nearby Work may harm the concrete's initial set or strength.

When a foundation excavation contains water, the Contractor shall pump it dry before placing concrete. If this is impossible, an underwater concrete seal shall be placed that complies with Section 6-02.3(6)B. This seal shall be thick enough to resist any uplift.

All foundations and forms shall be moistened with water just before the concrete is placed. Any standing water on the foundation or in the form shall be removed.

The Contractor shall place concrete in the forms as soon as possible after mixing. The concrete shall always be plastic and workable. For this reason, the Engineer may reduce the time to discharge even further. Concrete placement shall be continuous, with no interruption longer than 30-minutes between adjoining layers unless the Engineer approves a longer time. Each layer shall be placed and consolidated before the preceding layer takes initial set. After initial set, the forms shall not be jarred, and projecting ends of reinforcing bars shall not be disturbed.

In girders or walls, concrete shall be placed in continuous, horizontal layers 1.5 to 2.5-feet deep. Compaction shall leave no line of separation between layers. In each part of a form, the concrete shall be deposited as near its final position as possible.

Any method for placing and consolidating shall not segregate aggregates or displace reinforcing steel. Any method shall leave a compact, dense, and impervious concrete with smooth faces on exposed surfaces. Plastering is not permitted. Any section of defective concrete shall be removed at the Contractor's expense.

To prevent aggregates from separating, the length of any conveyor belt used to transport concrete shall not exceed 300-feet. If the mix needs protection from sun or rain, the Contractor shall cover the belt. When concrete pumps are used for placement, a Contractor's representative shall, prior to use on the first placement of each day, visually inspect the pumps water chamber for water leakage. No pump shall be used that allows free water to flow past the piston.

If a concrete pump is used as the placing system, the pump priming slurry shall be discarded before placement. Initial acceptance testing may be delayed until the pump priming slurry has been eliminated from the concrete being pumped. Eliminating the priming slurry from the concrete may require that several cubic yards of concrete are discharged through the pumping system and discarded. Use of a concrete pump requires a reserve pump (or other backup equipment) at the site.

If the concrete will drop more than 5-feet, it shall be deposited through a sheet metal (or other approved) conduit. If the form slopes, the concrete shall be lowered through approved conduit to keep it from sliding down 1 side of the form. No aluminum conduits or tremies shall be used to pump or place concrete.

Before placing concrete for roadway slabs on steel spans, the Contractor shall release the falsework under the bridge and let the span swing free on its supports. Concrete in flat slab bridges shall be placed in 1 continuous operation for each span or series of continuous spans.

Concrete for roadway slabs and the stems of T-beams or box-girders shall be placed in separate operations if the stem of the beam or girder is more than 3-feet deep. First the beam or girder stem shall be filled to the bottom of the slab fillets. Roadway slab concrete shall not be placed until enough time has passed to permit the earlier concrete to shrink (at least 12-hours). If stem depth is 3-feet or less, the Contractor may place concrete in 1 continuous operation if the Engineer approves.

Between expansion or construction joints, concrete in beams, girders, roadway slabs, piers, columns, walls, and traffic and pedestrian barriers, etc., shall be placed in a continuous operation.

No traffic or pedestrian barrier shall be placed until after the roadway slabs are complete for the entire Structure. No concrete barriers shall be placed until the falsework has been released and the span supports itself. The Contractor may choose not to release the deck overhang falsework prior to the barrier placement. The Contractor shall submit calculations to the Engineer indicating the loads induced into the girder webs due to the barrier weight and any live load placed on the Structure do not exceed the design capacity of the girder component. This analysis is not required for bridges with concrete Superstructures. No barrier, curb, or sidewalk shall be placed on steel or prestressed concrete girder bridges until the roadway slab reaches a compressive strength of at least 3,000-psi.

The Contractor may construct traffic and pedestrian barriers by the slipform method. However, the barrier may not deviate more than ¼-inch when measured by a 10-foot straightedge held longitudinally on the front face, back face, and top surface. Electrical conduit within the barrier shall be constructed in accordance with the requirements of Section 8-20.3(5).

When placing concrete in arch rings, the Contractor shall ensure that the load on the falsework remains symmetrical and uniform.

Unless the Engineer approves otherwise, arch ribs in open spandrel arches shall be placed in sections. Small key sections between large sections shall be filled after the large sections have shrunk.

6-02.3(6)A Weather and Temperature Limits to Protect Concrete

Hot Weather Protection

The Contractor shall provide concrete within the specified temperature limits by:

1. Shading or cooling aggregate piles (sprinkling of fine aggregate piles with water is not allowed). If sprinkling of the coarse aggregates is to be used, the piles moisture content shall be monitored and the mixing water adjusted for the free water in the aggregate. In addition, when removing the coarse aggregate, it shall be removed from at least 1-foot above the bottom of the pile.

2. Refrigerating mixing water; or replacing all or part of the mixing water with crushed ice, provided the ice is completely melted by placing time.

If the concrete would probably exceed 90°F using normal methods, the Engineer may require approved temperature-reduction measures be taken before the placement begins.

If air temperature exceeds 90°F, the Contractor shall use water spray or other approved methods to cool all concrete-contact surfaces to less than 90°F. These surfaces include forms, reinforcing steel, steel beam flanges, and any others that touch the mix. The Contractor shall reduce the time between mixing and placing to a minimum and shall not permit mixer trucks to remain in the sun while waiting to discharge concrete. Chutes, conveyors, and pump lines shall be shaded.

If bridge roadway slabs are placed while air temperature exceeds 90°F, the Contractor shall:

1. Cover the top layer of reinforcing steel with clean, wet burlap immediately before concrete placement;
2. Sprinkle cool water on the forms and reinforcing steel just before the placement if the Engineer requires it;
3. Finish the concrete slab without delay; and
4. Provide at the site water-fogging equipment to be used if needed after finishing to prevent plastic cracks.

If the evaporation rate at the concreting site is 0.10-pounds per square foot of surface per hour or more (determined from Table 6-02.3(6)), the Contractor shall surround the fresh concrete with an enclosure. This enclosure will protect the concrete from wind blowing across its surface until the curing compound is applied. If casting deck concrete that is 80°F or hotter, the Contractor shall install approved equipment at the site to show relative humidity and wind velocity.

Cold Weather Protection

This Specification applies when the weather forecast predicts air temperatures below 35°F at any time during the 7-days following concrete placement. The weather forecast is based on predictions from the Western Region Headquarters of the National Weather Service. This forecast can be found at http://www.wrh.noaa.gov/.

To achieve adequate curing, the temperature of the concrete shall be maintained above 50°F during the entire curing period or 7-days, whichever is greater. The concrete temperature shall not be allowed to fall below 35°F during this time. Prior to placing concrete in cold weather, the Contractor shall provide a written procedure for cold weather concreting to the Engineer. The procedure shall detail how the Contractor will adequately cure the concrete and prevent the concrete temperature from falling below 35°F. Extra protection shall be provided for areas especially vulnerable to freezing (such as exposed top surfaces, corners and edges, thin sections, and concrete placed into steel forms). Concrete placement will only be allowed if the Contractor's cold weather protection plan has been approved by the Engineer.

The Contractor shall not mix nor place concrete while the air temperature is below 35°F, unless the water or aggregates (or both) are heated to at least 70°F. The aggregate shall not exceed 150°F. If the water is heated to more than 150°F, it shall be mixed with the aggregates before the cement is added. Any equipment and methods shall heat the materials evenly. Concrete placed in shafts and piles is exempt from such preheating requirements.

The Contractor may warm stockpiled aggregates with dry heat or steam, but not by applying flame directly or under sheet metal. If the aggregates are in bins, steam or water coils or other heating methods may be used if aggregate quality is not affected. Live steam heating is not permitted on or through aggregates in bins. If using dry heat, the Contractor shall increase mixing time enough to permit the super-dry aggregates to absorb moisture.

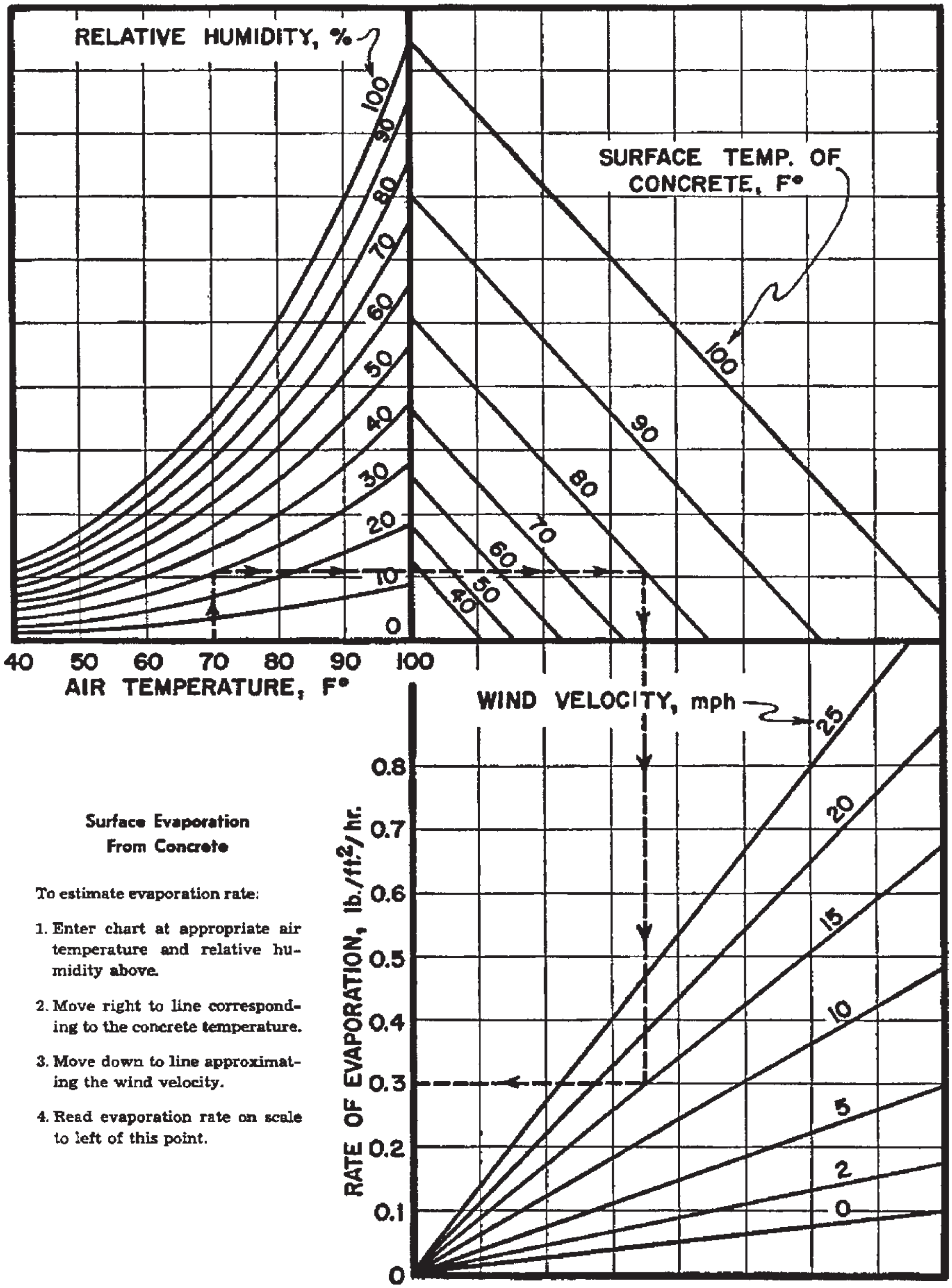
The Contractor shall provide and maintain a maturity meter sensor, continuously recording time and temperature during the curing period, in the concrete at a location specified by the Engineer for each concrete placement. The Contractor shall also provide recording thermometers or other approved devices to monitor the surface temperature of the concrete. During curing, data from the maturity meter and recording thermometer shall be readily available to the Engineer. The Contractor shall record time and temperature data on hourly intervals. Data shall be provided to the Engineer upon request.

Starting immediately after placement, the concrete temperatures measured by the maturity meter and recording thermometer shall be maintained at or above 50°F and the relative humidity shall be maintained above 80-percent. These conditions shall be maintained for a minimum of 7-days or for the cure period required by Section 6-02.3(11), whichever is longer. During this time, if the temperature falls below 50°F on the maturity meter or recording thermometer, no curing time is awarded for that day. Should the Contractor fail to adequately protect the concrete and the temperature of the concrete falls below 35°F during curing, the Engineer may reject it.

The Contractor is solely responsible for protecting concrete from inclement weather during the entire curing period. Permission given by the Engineer to place concrete during cold weather will in no way ensure acceptance of the Work by the Contracting Agency. Should the concrete placed under such conditions prove unsatisfactory in any way, the Engineer shall still have the right to reject the Work although the plan and the Work were carried out with the Engineer's permission.

Surface Evaporation from Concrete

Table 6-02.3(6)



6-02.3(6)B Placing Concrete in Foundation Seals

If the Plans require a concrete seal, the Contractor shall place the concrete underwater inside a watertight cofferdam, tube, or caisson. Seal concrete shall be placed in a compact mass in still water. It shall remain undisturbed and in still water until fully set. While seal concrete is being deposited, the water elevation inside and outside the cofferdam shall remain equal to prevent any flow through the seal in either direction. The cofferdam shall be vented at the vent elevation shown in the Plans. The thickness of the seal is based upon this vent elevation.

The seal shall be at least 18-inches thick unless the Plans show otherwise. The Engineer may change the seal thickness during construction which may require redesign of the footing and the pier shaft or column. Although seal thickness changes may result in the use of more or less concrete, reinforcing steel, and excavation, payment will remain as originally defined in unit Contract prices.

To place seal concrete underwater, the Contractor shall use a concrete pump or tremie. The tremie shall have a hopper at the top that empties into a watertight tube at least 10-inches in diameter. The discharge end of the tube on the tremie or concrete pump shall include a device to seal out water while the tube is first filled with concrete. Tube supports shall permit the discharge end to move freely across the entire Work area and to drop rapidly to slow or stop the flow. One tremie may be used to concrete an area up to 18-feet per side. Each additional area of this size requires 1 additional tremie.

Throughout the underwater concrete placement operation, the discharge end of the tube shall remain submerged in the concrete and the tube shall always contain enough concrete to prevent water from entering. The concrete placement shall be continuous until the Work is completed, resulting in a seamless, uniform seal. If the concreting operation is interrupted, the Engineer may require the Contractor to prove by core drilling or other tests that the seal contains no voids or horizontal joints. If testing reveals voids or joints, the Contractor shall repair them or replace the seal at no expense to the Contracting Agency.

Concrete Class 4000W shall be used for seals, and it shall meet the consistency requirements of Section 6-02.3(4)C.

6-02.3(6)C Dewatering Concrete Seals and Foundations

After a concrete seal is constructed, the Contractor shall pump the water out of the cofferdam and place the rest of the concrete in the dry. This pumping shall not begin until the seal has set enough to withstand the hydrostatic pressure (3-days for gravity seals and 10-days for seals containing piling or shafts). The Engineer may extend these waiting periods to ensure structural safety or to meet a condition of the operating permit.

If weighted cribs are used to resist hydrostatic pressure at the bottom of the seal, the Contractor shall anchor them to the foundation seal. Any method used (such as dowels or keys) shall transfer the entire weight of the crib to the seal.

No pumping shall be done during or for 24-hours after concrete placement unless done from a suitable sump separated from the concrete Work by a watertight wall. Pumping shall be done in a way that rules out any chance of concrete being carried away.

6-02.3(6)D Protection Against Vibration

Freshly placed concrete shall not be subjected to excessive vibration and shock waves during the curing period until it has reached a 2000-psi minimum compressive strength for concrete Class 4000 and lower strength classes of concrete. For higher strength classes of concrete, the minimum compressive strength for ending the vibration restriction shall be the concrete Class designation (specified in psi) divided by 2.

After the first 5-hours from the time the concrete has been placed and consolidated, the Contractor shall keep all vibration producing operations at a safe horizontal distance from the freshly placed concrete by following either the prescriptive safe distance method or the monitoring safe distance method. These requirements for the protection of freshly placed concrete against vibration shall not apply for plant cast concrete, shaft installation or soldier pile shaft installation operations, nor shall they apply to the vibrations caused by the traveling public. See the Shaft Special Provision, and Section 6-16 respectively for shaft installation, and soldier pile shaft installation operations.

Prescriptive Safe Distance Method

After the concrete has been placed and consolidated, the Contractor shall keep all vibration producing operations at a safe horizontal distance from the freshly placed concrete as follows:

MINIMUM COMPRESSIVE STRENGTH, f 'c	SAFE HORIZONTAL DISTANCE (1)	
	EQUIPMENT CLASS L (2)	EQUIPMENT CLASS H (3)
< 1000-psi	75-feet	125-feet
1000-psi to < 1400-psi	30-feet	50-feet
1400-psi to 2000-psi	15-feet	25-feet

(1) The safe horizontal distance shall be reduced to 10-feet for small rubber tire construction equipment like backhoes under 50,000-pounds, concrete placing equipment, and legal Highway vehicles if such equipment travels at speeds of:
- ≤ 5-mph on relatively smooth Roadway surfaces or
- ≤ 3-mph on rough Roadway surfaces (i.e. with potholes)

(2) Equipment Class L (Low Vibration) shall include tracked dozers under 85,000-pounds, track vehicles, trucks (unless excluded above), hand operated jack hammers, cranes, auger drill rig, caisson drilling, vibratory roller compactors under 30,000-pounds.

(3) Equipment Class H (High Vibration) shall include pile drivers, machine operated impact tools, pavement breakers, and other large pieces of equipment.

After the concrete has reached a minimum compressive strength specified above, the safe horizontal distance restrictions would no longer apply.

Monitoring Safe Distance Method

The Contractor may monitor the vibration producing operations in order to decrease the safe horizontal distance requirements of the prescriptive safe distance method. If this method is chosen, all construction operations that produce vibration or shock waves in the vicinity of freshly placed concrete shall be monitored by the Contractor with monitoring equipment sensitive enough to detect a minimum peak particle velocity (PPV) of 0.10-inches per second. Monitoring devices shall be placed on or adjacent to the freshly placed concrete when the measurements are taken. During the time subsequent to the concrete placement, the Contractor shall cease all vibration or shock producing operations in the vicinity of the newly placed concrete when the monitoring equipment detects excessive vibration and shock waves defined as exceeding the following PPV's:

MINIMUM COMPRESSIVE STRENGTH, f ’c	MAXIMUM PPV
< 1000-psi	0.10-in/sec
1000-psi to < 1400-psi	1.0-in/sec
1400-psi to 2000-psi	2.0-in/sec

After the concrete has reached a minimum compressive strength specified above, the safe horizontal distance restrictions would no longer apply.

6-02.3(7) Concrete Exposed to Sea Water

If sea water will contact a completed concrete Structure, the Contractor shall:

1. Mix the concrete for at least 2-minutes.
2. Control water content to produce concrete that will be as impermeable as possible.
3. Compact the concrete as the Engineer may require, avoiding the formation of any stone pockets.
4. Place only clean, rust-free reinforcement bars in the concrete.
5. Coat form surfaces heavily with shellac and any approved form release agent.
6. Leave forms intact for at least 30-days after concrete placement (longer if the Engineer requires) to prevent sea water from contacting the concrete.
7. Leave the surface of concrete just as it comes from the forms.
8. Provide special handling for any concrete piles used in sea water to avoid even slight deformation cracks.

The Engineer shall decide the range of disintegration possible by exposure to sea water. This range shall extend from a point below the level of extreme low tide up to a point above the level of extreme high tide. Wave action and other conditions will also affect the Engineer’s decision on this range. Unless the Engineer approves otherwise, the Contractor shall not locate construction joints within this range. All concrete within this range shall be poured in the dry.

6-02.3(8) Concrete Exposed to Alkaline Soils or Water

The requirements for concrete in seawater shall also apply to concrete in alkaline soils or water. In addition, the Contractor shall:

1. Let the concrete set at least 30-days (longer if possible) before allowing soil or water to contact it directly;
2. Vibrate each batch of concrete immediately after it has been placed into the forms, using enough vibrating tampers to do this effectively; and
3. Hand tamp, if necessary, to produce smooth, dense outside surfaces.

6-02.3(9) Vibration of Concrete

The Contractor shall supply enough vibrators to consolidate the concrete (except that placed underwater) according to the requirements of this section. Each vibrator must:

1. Be designed to operate while submerged in the concrete,
2. Vibrate at a rate of at least 7,000-pulses per minute, and
3. Receive the Engineer’s approval on its type and method of use.

Immediately after concrete is placed, vibration shall be applied in the fresh batch at the point of deposit. In doing so, the Contractor shall:

1. Space the vibrators evenly, no farther apart than twice the radius of the visible effects of the vibration;
2. Ensure that vibration intensity is great enough to visibly affect a weight of 1-inch slump concrete across a radius of at least 18-inches;
3. Insert the vibrators slowly to a depth that will effectively vibrate the full depth of each layer, penetrating into the previous layer on multilayer pours;
4. Protect partially hardened concrete (i.e., nonplastic, which prevents vibrator penetration when only its own weight is applied) by preventing the vibrator from penetrating it or making direct contact with steel that extends into it;
5. Not allow vibration to continue in one place long enough to form pools of grout;
6. Continue vibration long enough to consolidate the concrete thoroughly, but not so long as to segregate it;
7. Withdraw the vibrators slowly when the process is complete; and
8. Not use vibrators to move concrete from one point to another in the forms.

When vibrating and finishing top surfaces that will be exposed to weather or wear, the Contractor shall not draw water or laitance to the surface. In high lifts, the top layer shall be shallow and made up of a concrete mix as stiff as can be effectively vibrated and finished.

To produce a smooth, dense finish on outside surfaces, the Contractor shall hand tamp the concrete.

6-02.3(10) Roadway Slabs and Bridge Approach Slabs

A pre-concreting conference shall be held 5 to 10-working days before placing concrete to discuss construction procedures, personnel, and equipment to be used. Those attending shall include:

1. (representing the Contractor) The superintendent and all foremen in charge of placing steel reinforcing bars, of placing the concrete, and of finishing it; and
2. (representing the State) The Project Engineer and key inspection assistants.

If the project includes more than 1 slab, and if the Contractor's key personnel change between concreting operations, an additional conference shall be held just before each slab is placed.

The Contractor shall not place roadway slabs until the Engineer agrees that:

1. Concrete producing and placement rates will be high enough to meet placing and finishing deadlines,
2. Finishers with enough experience have been employed, and
3. Adequate finishing tools and equipment are at the site.

The finishing machine shall be self-propelled and be capable of forward and reverse movement under positive control. The finishing machine shall be equipped with a rotating cylindrical single or double drum screed not exceeding 60-inches in length. The finishing machine shall have the necessary adjustments to produce the required cross-section, line, and grade. Provisions shall be made for the raising and lowering of all screeds under positive control. The upper vertical limit of screed travel shall permit the screed to clear the finished concrete surface. When placing concrete abutting a previously placed slab, the side of the finishing machine adjacent to the existing slab shall be equipped to travel on the existing slab.

For bridge deck and bridge approach slab widening of 20-feet or less, or where jobsite conditions do not allow the use of conventional configuration finishing machines described above, the Contractor may propose the use of a hand operated motorized power screed such as a “texas” or “bunyan” screed. This screed shall be capable of finishing the bridge deck and bridge approach slab to the same standards as the finishing machine. The Contractor shall not begin placing bridge deck or bridge approach slab concrete until receiving the Engineer’s approval of this screed and the placing procedures.

On Roadway slabs the Contractor may use hand-operated strike-boards only when the Engineer approves for special conditions and small areas (less than 10-feet in width and 200-feet in length). These boards must be sturdy and able to strike off the full placement width without intermediate supports. Strike-boards, screed rails, and any specially made auxiliary equipment shall receive the Engineer’s approval before use. All finishing requirements in these Specifications apply to hand-operated finishing equipment.

Screed rails shall rest on adjustable supports that can be removed with the least possible disturbance to the screeded concrete. The supports shall rest on structural members or on forms rigid enough to resist deflection. Supports shall be removable to at least 2-inches below the finished surface. If possible, the Contractor shall place screed rails outside the finishing area. But if they are placed inside the area, they shall be placed above the finished surface.

Screed rails (with their supports) shall be strong enough and stiff enough to permit the finishing machine to operate effectively on them. All screed rails shall be placed and secured for the full length of the slab before the concreting begins. If the Engineer approves in advance, the Contractor may move rails ahead onto previously set supports while concreting progresses. But such movable rails and their supports shall not change the set elevation of the screed.

On steel truss and girder spans, screed rails and bulkheads may be placed directly on transverse steel floorbeams, with the strike-board moving at right angles to the centerline of the Roadway.

Before any concrete is placed, the finishing machine shall be operated over the entire length of the slab to check screed deflection. Concrete placement may begin only if the Engineer approves after this test.

Immediately before placing concrete, the Contractor shall check (and adjust if necessary) all falsework and wedges to minimize settlement and deflection from the added mass of the concrete slab. The Contractor shall also install devices, such as telltales, by which the Engineer can readily measure settlement and deflection.

The Contractor shall schedule the concrete placement so that it can be completely finished during daylight. After dark finishing is permitted if the Engineer approves and if the Contractor provides adequate lighting.

The placement operation shall cover the full width of the Roadway or the full width between construction joints. The Contractor shall locate any construction joint over a beam or web that can support the slab on either side of the joint. The joint shall not occur over a pier unless the Plans permit. Each joint shall be formed vertically and in true alignment. The Contractor shall not release falsework or wedges supporting pours on either side of a joint until each side has aged as these Specifications require.

Placement of concrete for Roadway and bridge approach slabs shall comply with Section 6-02.3(6). The Engineer shall approve the placement method. In placing the concrete, the Contractor shall:

1. Place it (without segregation) against concrete placed earlier, as near as possible to its final position, approximately to grade, and in shallow, closely spaced piles;
2. Consolidate it around reinforcing steel by using vibrators before strike-off by the finishing machine;
3. Not use vibrators to move concrete;
4. Not revibrate any concrete surface areas where workers have stopped prior to screeding;
5. Remove any concrete splashed onto reinforcing steel in adjacent segments before concreting them;
6. Tamp and strike off the concrete with a template or strike board moving slowly forward at an even speed;
7. Maintain a slight excess of concrete in front of the cutting edge across the entire width of the placement operation;
8. Make enough passes with the strike-board (without bringing excessive amounts of mortar to the surface) to create a surface that is true and ready for final finish; and
9. Leave a thin, even film of mortar on the concrete surface after the last pass of the strike-board.

Workers shall complete all post screeding operations without walking on the concrete. This may require work bridges spanning the full width of the slab.

After removing the screed supports, the Contractor shall fill the voids with concrete (not mortar).

If necessary, as determined by the Engineer, the Contractor shall float the surface left by the finishing machine to remove roughness, minor irregularities, and seal the surface of the concrete. Floating shall leave a smooth and even surface. The floats shall be at least 4-feet long. Each transverse pass of the float shall overlap the previous pass by at least half the length of the float. The first floating shall be at right angles to the strike-off. The second floating shall be at right angles to the centerline of the span. A smooth riding surface shall be maintained across construction joints.

Expansion joints shall be finished with a ½-inch radius edger.

After floating, but while the concrete remains plastic, the Contractor shall test the entire slab for flatness (allowing for crown, camber, and vertical curvature). The testing shall be done with a 10-foot straightedge held on the surface. The straightedge shall be advanced in successive positions parallel to the centerline, moving not more than ½ the length of the straightedge each time it advances. This procedure shall be repeated with the straightedge held perpendicular to the centerline. An acceptable surface shall be one free from deviations of more than ⅛-inch under the 10-foot straightedge.

If the test reveals depressions, the Contractor shall fill them with freshly mixed concrete, strike off, consolidate, and refinish them. High areas shall be cut down and refinished. Retesting and refinishing shall continue until an acceptable, deviation free surface is produced. The hardened concrete shall meet all smoothness requirements of these Specifications even though the tests require corrective Work.

The Contractor shall texture the bridge deck and bridge approach slab by combing the final surface perpendicular to the centerline. Made of a single row of metal tines, the comb shall leave striations in the fresh concrete approximately $^{3}/_{16}$-inch deep by ⅛-inch wide and spaced approximately ½-inch apart. The Engineer will decide actual depths at the site. (If the comb has not been approved, the Contractor shall obtain the Engineer's approval by demonstrating it on a test section.)

The Contractor may operate the combs manually or mechanically, either singly or with several placed end to end. The timing and method used shall produce the required texture without displacing larger particles of aggregate. Texturing shall end 2-feet from curb lines. This 2-foot untextured strip shall be hand finished with a steel trowel.

If the Plans call for an overlay (to be constructed under the same Contract), such as hot mix asphalt, latex modified concrete, epoxy concrete, or similar, the Contractor shall produce the final finish by dragging a strip of damp, seamless burlap lengthwise over the full width of the slab or by brooming it lightly. A burlap drag shall equal the slab in width. Approximately 3-feet of the drag shall contact the surface, with the least possible bow in its leading edge. It must be kept wet and free of hardened lumps of concrete. When it fails to produce the required finish, the Contractor shall replace it. When not in use, it shall be lifted clear of the slab.

After the slab has cured, the surface shall not vary more than ⅛-inch under a 10-foot straightedge placed parallel and perpendicular to the centerline.

The Contractor shall cut high spots down with a diamond faced, saw-type cutting machine. This machine shall cut through mortar and aggregate without breaking or dislodging the aggregate or causing spalls.

Low spots shall be built up utilizing a grout or concrete with a strength equal to or greater than the required 28-day strength of the roadway slab. The method of build-up shall be submitted to the Engineer for approval.

The surface texture on any area cut down or built up shall match closely that of the surrounding bridge deck or bridge approach slab area. The entire bridge Roadway slab and bridge approach slab shall provide a smooth riding surface.

Concrete for sidewalk slabs shall be well compacted, struck off with a strike-board, and floated with a wooden float to achieve a surface that does not vary more than ⅛-inch under a 10-foot straightedge. An edging tool shall be used to finish all sidewalk edges and expansion joints. The final surface shall have a granular texture that will not turn slick when wet.

Bridge approach slabs shall be constructed full bridge deck width from outside usable Shoulder to outside usable Shoulder at an elevation to match the Structure. The bridge approach slabs shall be modified as shown in the Plans to accommodate the grate inlets at the bridge ends if the grate inlets are required.

Bridge approach slab anchors shall be installed as detailed in the Plans and the anchor rods, couplers, and nuts shall conform to Section 9-06.5(1). The steel plates shall conform to ASTM A 36. All metal parts shall receive 1 coat of formula A-11-99 paint meeting the requirements of Section 9-08.2. The pipe shall be any non-perforated PE or PVC pipe of the diameter specified in the Plans. Polystyrene shall conform to Section 9-04.6. The anchors shall be installed parallel both to profile grade and center line of Roadway. The Contractor shall secure the anchors to ensure that they will not be misaligned during concrete placement. For Method B anchors installations, the epoxy bonding agent used to install the anchors shall be Type IV conforming to Section 9-26.1.

The compression seal shall be as noted in the Contract documents. Dowel bars shall be installed in the bridge approach slabs in accordance with the requirements of the Standard Plans and Section 5-05.3(10).

After curing bridge approach slabs in accordance with Section 6-02.3(11), the bridge approach slabs may be opened to traffic in accordance with Section 5-05.3(17).

6-02.3(11) Curing Concrete

After placement, concrete surfaces shall be cured as follows:

1. Bridge roadway slabs (except those made of concrete Class 4000D), flat slab bridge Superstructures, bridge sidewalks, roofs of cut and cover tunnels — curing compound covered by white, reflective type sheeting or continuous wet curing. Curing by either method shall be for at least 10-days.
2. Class 4000D concrete (regardless of Structure type) — 2 coats of curing compound and continuous wet cure using heavy quilted blankets or burlap for 14-days.
3. Bridge approach slabs (Class 4000A concrete) – 2 coats of curing compound and continuous wet cure using heavy quilted blankets or burlap for 10-days.
4. All other concrete surfaces (except traffic barriers and rail bases) — continuous moisture for at least 3-days. When continuous moisture or wet curing is required, the Contractor shall keep the concrete surfaces wet with water during curing.

The Contractor may provide continuous moisture by watering a covering of heavy quilted blankets, by keeping concrete surfaces wet with water continuously and covering with a white reflective type sheeting, or by wetting the outside surfaces of wood forms. Runoff water shall be collected and disposed of in accordance with all applicable regulations. In no case shall runoff water be allowed to enter any lakes, streams, or other surface waters.

When curing Class 4000D and 4000A, 2 coats of curing compound that complies with Section 9-23.2 shall be applied immediately (not to exceed 15 min.) after tining any portion of the bridge deck or bridge approach slab. The surface shall be covered with presoaked heavy quilted blankets or burlap as soon as the concrete has set enough to allow covering without damaging the finish. Soaker hoses are required and shall be placed on top of burlap or blankets and shall be charged with water frequently to keep the entire deck covering wet during the course of curing.

For all other concrete requiring curing compound, the Contractor shall apply 2 coats (that complies with Section 9-23.2) to the fresh concrete. The compound shall be applied immediately after finishing. Application of the second coat shall run at right angles to that of the first. The 2 coats shall total at least 1-gallon per 150-square feet and shall obscure the original color of the concrete. If any curing compound spills on construction joints or reinforcing steel, the Contractor shall clean it off before the next concrete placement.

If the Plans call for an asphalt overlay, the Contractor shall use the clear curing compound (Type 1D), applying at least 1-gallon per 150-square feet to the concrete surface. Otherwise, the Contractor shall use white pigmented curing compound (Type 2), agitating it thoroughly just before and during application. If other materials are to be bonded to the surface, the Contractor shall remove the curing compound by sandblasting or acceptable high pressure water washing.

The Contractor shall have on the site, back-up spray equipment, enough workers, and a bridge from which they will apply the curing compound. The Engineer may require the Contractor to demonstrate (at least 1-day before the scheduled concrete placement) that the crew and equipment can apply the compound acceptably.

The Contractor shall cover the top surfaces with white, reflective sheeting, leaving it in place for at least 10-days. Throughout this period, the sheeting shall be kept in place by taping or weighting the edges where they overlap.

The unit Contract prices shall cover all concrete curing costs.

6-02.3(11)A Curing and Finishing Concrete Traffic and Pedestrian Barrier

The Contractor shall supply enough water and workers to cure and finish concrete barrier as required in this section. Unit contract prices shall cover all curing and finishing costs.

Fixed-Form Barrier

The edge chamfers shall be formed by attaching chamfer strips to the barrier forms.

After troweling and edging a barrier (while the forms remain in place), the Contractor shall:

1. Brush the top surface with a fine bristle brush;
2. Cover the top surface with heavy, quilted blankets; and
3. Spray water on the blankets and forms at intervals short enough to keep them thoroughly wet for 3-days.

After removing the forms, the Contractor shall:

1. Remove all lips and edgings with sharp tools or chisels;
2. Fill all holes with mortar;
3. True up corners of openings;
4. Remove concrete projecting beyond the true surface by stoning or grinding;
5. Cover the barrier with heavy, quilted blankets (not burlap);
6. Keep the blankets continuously wet for at least 7-days.

The Contractor may do the finishing Work described in steps 1 through 4 above during the second (the 7-day) curing period if the entire barrier is kept covered except the immediate Work area. Otherwise, no finishing Work may be done until at least 10-days after pouring.

After the 10-day curing period, the Contractor shall remove from the barrier all form-release agent, mud, dust, and other foreign substances in either of 2 ways: (1) by light sandblasting and washing with water, or (2) by spraying with a high-pressure water jet. The water jet equipment shall use clean fresh water and shall produce (at the nozzle) at least 1,500-psi with a discharge of at least 3-gpm. The water jet nozzle shall have a 25-degree tip and shall be held no more than 9-inches from the surface being washed.

After cleaning, the Contractor shall use brushes to rub 1:1 mortar into air holes and small crevices on all surfaces except the brushed top. This mortar shall consist of 1 part Portland cement (of the same brand used in the concrete) and 1 part clean, fine plaster sand. As soon as the mortar takes its initial set, the Contractor shall rub it off with a piece of sacking or carpet. The barrier shall then be covered with wet blankets for at least 48-hours.

No curing compound shall be used on fixed-form concrete barrier. The completed surface of the concrete shall be even in color and texture.

Slip-Form Barrier

The edge radius shall be formed by attaching radius strips to the barrier slip form.

The Contractor shall finish slip-form barrier by: (1) steel troweling to close all surface pockmarks and holes; and (2) for plain surface barrier, lightly brushing the front and back face with vertical strokes and the top surface with transverse strokes.

After finishing, the Contractor shall cure the slip-form barrier by using either method A (curing compound) or B (wet blankets) described below.

Method A. Under the curing compound method, the Contractor shall:

1. Spray 2 coats of clear curing compound (Type 1D) on the concrete surface after the free water has disappeared. (Coverage of combined coats shall equal at least 1-gallon per 150-square feet.)
2. No later than the morning after applying the curing compound, cover the barrier with white, reflective sheeting for at least ten-days.
3. After the 10-day curing period, remove the curing compound as necessary by light sandblasting or by spraying with a high-pressure water jet to produce an even surface appearance. The water jet equipment shall use clean fresh water and shall produce (at the nozzle) at least 2,500-psi with a discharge of at least 4 gpm. The water jet nozzle shall have a 25-degree tip and shall be held no more than 9-inches from the surface being cleaned. The Contractor may propose to use a curing compound/concrete sealer. The Engineer will evaluate the proposal and if found acceptable, shall approve the proposal in writing. As a minimum, the Contractor's proposal shall include:

    Product identity

    Manufacturer's recommended application rate

    Method of application and necessary equipment

    Material Safety Data Sheet (MSDS)

    Sample of the material for testing

    Allow 14-working days for evaluating the proposal and testing the material.

Method B. Under the wet cure method, the Contractor shall:

1. Provide an initial cure period by continuous fogging or mist spraying for at least the first 24-hours.
2. After the initial cure period, cover the barrier with a heavy quilted blanket.
3. Keep the blankets continuously wet for at least 10-days. (No additional finishing is required at the end of the curing period.)

6-02.3(12) Construction Joints

If the Engineer approves, the Contractor may add, delete, or relocate construction joints shown in the Plans. Any request for such changes shall be in writing, accompanied by a drawing that depicts them. The Contractor will bear any added costs that result from such changes.

All construction joints shall be formed neatly with grade strips or other approved methods. The Contracting Agency will not accept irregular or wavy pour lines. Wire mesh forming material shall not be used. All joints shall be horizontal, vertical, or perpendicular to the main reinforcement. The Contractor shall not use an edger on any construction joint, and shall remove any lip or edging before making the adjacent pour.

If the Plans require a roughened surface on the joint, the Contractor shall strike it off to leave grooves at right angles to the length of the member. The grooves shall be ½-inch to 1-inch wide, ¼-inch to ½-inch deep, and spaced equally at twice the width of the groove. If the first strike-off does not produce the required roughness, the Contractor shall repeat the process before the concrete reaches initial set. The final surface shall be clean and without laitance or loose material.

If the Plans do not require a roughened surface, the Contractor shall include shear keys at all construction joints. These keys shall provide a positive, mechanical bond. Shear keys shall be formed depressions and the forms shall not be removed until the concrete has been in place at least 12-hours. Forms shall be slightly beveled to ensure ready removal. Raised shear keys are not allowed.

Shear keys for the tops of beams, at tops and bottoms of boxed girder webs, in diaphragms, and in crossbeams shall:

1. Be formed with 2- by 8-inch wood blocks;
2. Measure 8-inches lengthwise along the beam or girder stem;
3. Measure 4-inches less than the width of the stem, beam, crossbeam, etc. (measured transverse of the stem); and
4. Be spaced at 16-inches center to center.

Unless the Plans show otherwise, in other locations (not named above), shear keys shall equal approximately ⅓ of the joint area and shall be approximately 1½-inches deep.

Before placing new concrete against cured concrete, the Contractor shall thoroughly clean and roughen the cured face and wet it with water. Before placing the reinforcing mat for footings on seals, the Contractor shall: (1) remove all scum, laitance, and loose gravel and sediment; (2) clean the construction joint at the top of the seals; and (3) chip off any high spots on the seals that would prevent the footing steel from being placed in the position required by the Plans.

6-02.3(13) Expansion Joints

This section outlines the requirements of specific expansion joints shown in the Plans. The Plans may require other types of joints, seals, or materials than those described here.

Joints made of a vulcanized, elastomeric compound (with neoprene as the only polymer) shall be installed with an approved lubricant adhesive as recommended by the manufacturer. The length of a seal shall match that required in the Plans without splicing or stretching.

Open joints shall be formed with a template made of wood, metal, or other suitable material. Insertion and removal of the template shall be done without chipping or breaking the edges or otherwise injuring the concrete.

Any part of an expansion joint running parallel to the direction of expansion shall provide a clearance of at least ½-inch (produced by inserting and removing a spacer strip) between the two surfaces. The Contractor shall ensure that the surfaces are precisely parallel to prevent any wedging from expansion and contraction.

All poured rubber joint sealer (and any required primer) shall conform with Section 9-04.2(2).

6-02.3(14) Finishing Concrete Surfaces

All concrete shall show a smooth, dense, uniform surface after the forms are removed. If it is porous, the Contractor shall bear the cost of repairing it. The Contractor shall clean and refinish any stained or discolored surfaces that may have resulted from their Work or from construction delays.

Subsections A and B (below) describe 2 classes of surface finishing.

6-02.3(14)A Class 1 Surface Finish

The Contractor shall apply a Class 1 finish to all surfaces of concrete members to the limits designated in the Contract Plans.

The Contractor shall follow steps 1 through 8 below. When steel forms have been used and when the surface of filled holes matches the texture and color of the area around them, the Contractor may omit steps 3 through 8. To create a Class 1 surface, the Contractor shall:

1. Remove all bolts and all lips and edgings where form members have met;
2. Fill all holes greater than ¼-inch with 1:2 mortar floated to an even, uniform finish;
3. Thoroughly wash the surface of the concrete with water;
4. Brush on a 1:1 mortar, working it well into the small air holes and other crevices in the face of the concrete;
5. Brush on no more mortar than can be finished in 1-day;
6. Rub the mortar off with burlap or a piece of carpet as soon as it takes initial set (before it reaches final set);
7. Fog-spray water over the finish as soon as the mortar paint has reached final set; and
8. Keep the surface damp for at least 2-days.

If the mortar becomes too hard to rub off as described in step 6, the Contractor shall remove it with a Carborundum stone and water. Random grinding is not permitted.

6-02.3(14)B Class 2 Surface Finish

The Contractor shall apply a Class 2 finish to all above-ground surfaces not receiving a Class 1 finish as specified above unless otherwise indicated in the Contract. Surfaces covered with fill do not require a surface finish.

To produce a Class 2 finish, the Contractor shall remove all bolts and all lips and edgings where form members have met and fill all form tie holes.

6-02.3(15) Date Numerals

Standard date numerals shall be placed where shown in the Plans. The date shall be for the year in which the Structure is completed. When traffic barrier is placed on an existing Structure, the date shall be for the year in which the original Structure was completed. Unit Contract prices shall cover all costs relating to these numerals.

6-02.3(16) Plans for Falsework and Formwork

The Contractor shall submit all plans for falsework and formwork for approval or preapproval directly to the Bridge and Structures Office, Construction Support Engineer, Washington State Department of Transportation, PO Box 47340, Olympia, WA 98504-7340 as described in Section 6-02.3(16)A or 6-02.3(16)B. The Contractor shall also submit 2 sets of the falsework and formwork plans to the Project Engineer. Approval will not reduce the Contractor's responsibility for ensuring the adequacy of the formwork and falsework. All falsework and formwork shall be constructed in accordance with approved falsework and formwork plans.

Except for the placement of falsework foundation pads and piles, the construction of any unit of falsework shall not start until the Engineer has reviewed and approved the falsework plans for that unit. Falsework driven piling, temporary concrete footings, or timber mudsills may be placed as described in Section 6-02.3(17)D prior to approval at the Contractor's own risk, except for the following conditions:

1. The falsework is over or adjacent to Roadways or railroads as described in Section 6-02.3(17)C, or
2. The falsework requires prior placement of shoring or cofferdams as described in Section 2-09.3(3)D.

Costs associated with modifying falsework to bring it into compliance with the approved falsework plans shall be at the Contractor's expense.

If the project involves a railroad or the U.S. Bureau of Reclamation, additional sets for the portion of the project that involves them shall be sent to:

If sent via US Postal Service:

Washington State Department of Transportation
Bridge and Structures Engineer
Construction Support
PO Box 47340
Olympia WA 98504-7340

If sent via FedEx:

Washington State Department of Transportation
Bridge and Structures Engineer
7345 Linderson Way SW
Tumwater, WA 98501-6504

1. Four sets for each railroad company affected, and
2. Six sets for the U.S. Bureau of Reclamation.

The Department will review the falsework and formwork plans and calculations, and if they are acceptable, will obtain the required approvals from the appropriate railroad company or the U.S. Bureau of Reclamation. After the Department has received approval and any comments from the railroad company or the U.S. Bureau of Reclamation, 2 copies of the falsework and formwork plans will then be marked with any comments and returned to the Contractor.

Plan approval is not required for footing or retaining walls unless they are more than 4-feet high (excluding pedestal height).

The design of falsework and formwork shall be based on:

1. Applied loads and conditions which are no less severe than those described in Section 6-02.3(17)A, "Design Loads;"
2. Allowable stresses and deflections which are no greater than those described in Section 6-02.3(17)B, "Allowable Stresses and Deflections;"
3. Special loads and requirements no less severe than those described in Section 6-02.3(17)C, "Falsework and Formwork at Special Locations;" and
4. Conditions required by other Sections of 6-02.3(17), Falsework and Formwork." Plan approval can be done by the Project Engineer for footings and walls 4-feet to 8-feet high (excluding pedestal height) provided:

5. Concrete placement rate is 4-feet per hour or less.
6. Facing is ¾-inch plywood with grade as specified per Section 6-02.3(17)J.
7. Studs, with plywood face grain perpendicular, are 2x4's spaced at 12-inches.
8. Walers with 3,000-pound safe working load ties spaced at 24-inches are 2-2x4's spaced at 24-inches.

Plan approval can be done by the Project Engineer for manufactured certified steel round column forming for column heights up to 20-feet. Concrete placement rate shall not exceed 10-feet per hour. Bracing requirements shall be per manufacturer's recommendations or submitted according to Section 6-02.3(16).

The falsework and formwork plans shall be scale drawings showing the details of proposed construction, including: sizes and properties of all members and components; spacing of bents, posts, studs, wales, stringers, wedges and bracing; rates of concrete placement, placement sequence, direction of placement, and location of construction joints; identify falsework devices and safe working load as well as identifying any bolts or threaded rods used with the devices including their diameter, length, type, grade, and required torque. Show in the falsework plans the proximity of falsework to utilities or any nearby Structures including underground Structures. Formwork accessories shall be identified according to Section 6-02.3(17)H, "Formwork Accessories." All assumptions, dimensions, material properties, and other data used in making the structural analysis shall be noted on the drawing.

The Contractor shall furnish 2 copies of the associated design calculations to the Bridge and Structures Office, Construction Support Engineer for examination as a condition for approval. The design calculations shall show the stresses and deflections in load supporting members. Construction details which may be shown in the form of sketches on the calculation sheets shall be shown in the falsework or formwork drawings as well. Falsework or formwork plans will not be approved in any case where it is necessary to refer to the calculation sheets for information needed for complete understanding of the falsework and formwork plans or how to construct the falsework and formwork.

All falsework and formwork plans and design calculations submitted to the Bridge and Structures Office shall be prepared by (or under the direct supervision of) a Professional Engineer, licensed under Title 18 RCW, State of Washington, in the branch of Civil or Structural Engineering.

Each sheet of falsework and formwork plans shall carry the following:

1. Professional Engineer's original signature, date of signature, original seal, registration number, and date of expiration.
2. The initials and dates of all participating design professionals.
3. Clear notation of all revisions including identification of who authorized the revision, who made the revision, and the date of the revision.
4. The Contract number, Contract title, and sequential sheet number. These shall also be on any related documents.
5. Identify where the falsework and formwork plan will be utilized by referencing Contract Plan sheet number and related item or detail.

Design calculations shall carry on the cover page, the Professional Engineer's original signature, date of signature, original seal, registration number, and date of expiration. The cover page shall include the Contract number, Contract title, and sequential index to calculation page numbers.

A State of Washington Professional Engineer, licensed under Title 18 RCW, state of Washington, in the branch of Civil or Structural Engineering may be retained to check, review and certify falsework and formwork plans and calculations of an individual who is licensed in another state provided that the following conditions are satisfied:

1. That the Work being reviewed was legally prepared by an individual holding valid registration in another state as a civil or structural engineer.
2. The Washington State Professional Engineer conducts independent calculations and reviews all technical matters contained within the subject Work, falsework and formwork plans, Contract Plans, Specifications, legal requirements, technical standards, other related documents; and has verified that the design meets all applicable Specifications and is in agreement with the specific site conditions and geometry.
3. All falsework and formwork plan sheets shall carry the Washington State Professional Engineer's original signature, date of signature, original seal, registration number, and date of expiration.
4. Two copies of the Washington State Professional Engineer's independent calculations shall be submitted to the Bridge and Structures Office, Construction Support Engineer for review along with the falsework and formwork plans. The independent calculations shall carry on the cover page the Washington State Professional Engineer's original signature, date of signature, original seal, registration number, and date of expiration. The cover page shall include the following: the Contract number, Contract title, and sequential index to calculation page numbers
5. The Washington State Professional Engineer shall keep, a signed and sealed copy of the falsework, formwork plans, independent calculations, Specifications and other related documentation that represents the extent of the review.

6-02.3(16)A Nonpreapproved Falsework and Formwork Plans

The Contractor shall submit 6 copies of all non-preapproved falsework and formwork plans, and 2 copies of the design calculations, directly to the following for review and approval and submit 2 copies of the falsework and formwork plans to the Project Engineer.

If sent via US Postal Service:

Washington State Department of Transportation
Bridge and Structures Engineer
Construction Support
PO Box 47340
Olympia WA 98504-7340

If sent via FedEx:

Washington State Department of Transportation
Bridge and Structures Engineer
Construction Support
7345 Linderson Way SW
Tumwater, WA 98501-6504

Reviewed falsework and formwork plans will be returned from the Bridge and Structures Office, Construction Support Engineer to the Project Engineer who will forward them to the Contractor within the time allowed according to Section 6-01.9. The time allowed begins when the Contractor's transmittal and submittal including all required copies of the falsework and/or formwork plans and calculations, catalog data, and other technical information are received by the Bridge and Structures Office, Construction Support Engineer. Fax copies are considered only informational. For multiple submittals or multiple parts to the same submittal and priority of review see Section 6-01.9.

Plans returned to the Contractor for correction shall be corrected and clean (without any previous WSDOT stamps and comments) revised falsework and formwork plans resubmitted to the Bridge and Structures Office, Construction Support Engineer for review and approval.

The Contractor may revise approved falsework and formwork plans, provided sufficient time is allowed for the Engineer's review and approval before construction is started on the revised portions. Such additional time will not be more than that which was originally allowed per Section 6-01.9. After a plan or drawing is approved and returned to the Contractor, all changes that the Contractor proposed shall be submitted to the Project Engineer for review and approval.

6-02.3(16)B Preapproved Formwork Plans

The Contractor may request preapproval on formwork plans for abutments, wingwalls, diaphragms, retaining walls, columns, girders and beams, box culverts, railings, and bulkheads. Plans for falsework supporting the roadway slab for interior spans between precast prestressed concrete girders may also be submitted for preapproval. Other falsework plans, however, will not be preapproved, but shall be submitted for review and approval as required in Section 6-02.3(16)A.

To apply for preapproval, the Contractor shall submit 1 reproducible drawing for each formwork plan sheet and 2 copies of the design calculations directly to:

If sent via US Postal Service:

Washington State Department of Transportation
Bridge and Structures Engineer
Construction Support
PO Box 47340
Olympia WA 98504-7340

If sent via Fedex:

Washington State Department of Transportation
Bridge and Structures Engineer
Construction Support
7345 Linderson Way SW
Tumwater, WA 98501-6504

The Bridge and Structures Office, Construction Support Engineer will return the formwork plan to the Contractor stamped "Preapproved" with an effective date of approval or will indicate any changes required for approval. The reviewed formwork plan will be returned from the Bridge and Structures Office, Construction Support Engineer to the Contractor within the time allowed according to Section 6-01.9. The time allowed begins when the Contractor's transmittal and submittal including all required information are received by the Bridge and Structures Office, Construction Support Engineer.

For each contract on which the preapproved formwork plans will be used, the Contractor shall submit 3 copies to the Project Engineer. Construction shall not begin until the Project Engineer has given approval.

If the forms being constructed have any deviations to the preapproved formwork plan, the Contractor shall submit formwork plan revisions for review and approval per Section 6-02.3(16)A.

6-02.3(17) Falsework and Formwork

Formwork and falsework are both structural systems. Formwork contains the lateral pressure exerted by concrete placed in the forms. Falsework supports the vertical and/or the horizontal loads of the formwork, reinforcing steel, concrete, and live loads during construction.

The Contractor shall set falsework, to produce in the finished Structure, the lines and grades indicated in the Contract Plans. The setting of falsework shall allow for shrinkage, settlement, falsework girder camber, and any structural camber the Plans or the Engineer require.

Concrete forms shall be mortar tight, true to the dimensions, lines, and grades of the Structure. Curved surfaces shown in the Contract Plans shall be constructed as curved surfaces and not chorded, except as allowed in Section 6-02.3(17)J. Concrete formwork shall be of sufficient strength and stiffness to prevent overstress and excess deflection as defined in Section 6-02.3(17)B. The rate of depositing concrete in the forms shall not exceed the placement rate in the approved formwork plan. The interior form shape and dimensions shall also ensure that the finished concrete will conform with the Contract Plans.

If the new Structure is near or part of an existing one, the Contractor shall not use the existing Structure to suspend or support falsework unless the Plans or Special Provisions state otherwise. For prestressed girder and T-beam bridge widenings or stage construction, the roadway deck and the diaphragm forms may be supported from the existing Structure or previous stage, if approved by the Engineer. For steel plate girder bridge widenings or stage construction, only the roadway deck forms may be supported from the existing Structure or previous stage, if approved by the Engineer. See Section 6-02.3(17)E for additional conditions.

On bridge roadway slabs, forms designed to stay in place made of steel or precast concrete panels shall not be used.

For post-tensioned Structures, both falsework and forms shall be designed to carry the additional loads caused by the post-tensioning operations. The Contractor shall construct supporting falsework in a way that leaves the Superstructure free to contract and lift off the falsework during post-tensioning. Forms that will remain inside box girders to support the placement of the roadway slab concrete shall, by design, resist girder contraction as little as possible. See Section 6-02.3(26) for additional conditions.

6-02.3(17)A Design Loads

The design load for falsework shall consist of the sum of dead and live vertical loads, and a design horizontal load. The minimum total design load for any falsework shall not be less than 100-lbs./sf. for combined live and dead load regardless of Structure thickness.

The entire Superstructure cross-section, except traffic barrier, shall be considered to be placed at one time for purposes of determining support requirements and designing falsework girders for their stresses and deflections, except as follows:

For concrete box girder bridges, the girder stems, diaphragms, crossbeams, and connected bottom slabs, if the stem wall is placed more than 5-days prior to the top slab, may be considered to be self supporting between falsework bents at the time the top slab is placed, provided that the distance between falsework bents does not exceed 4 times the depth of the portion of the girder placed in the preceding concrete placements.

Falsework bents shall be designed for the entire live load and dead load, including all load transfer that takes place during post-tensioning, and braced for the design horizontal load.

Dead loads shall include the weight of all successive placements of concrete, reinforcing steel, forms and falsework, and all load transfer that takes place during post-tensioning. The weight of concrete with reinforcing steel shall be assumed to be not less than 160-pounds per cubic foot.

Live loads shall consist of the actual mass of any equipment to be supported by falsework applied as concentrated loads at the points of contact, and a minimum uniform load of not less than 25-lbs./sf. applied over the entire falsework plan area supported, plus a minimum load of not less than 75-pounds per linear foot applied at the outside edge of deck overhangs.

The design horizontal load to be resisted by the falsework bracing system in any direction shall be:

The sum of all identifiable horizontal loads due to equipment, construction sequence, side-sway caused by geometry or eccentric loading conditions, or other causes, and an allowance for wind plus an additional allowance of 1-percent of the total dead load to provide for unexpected forces. In no case shall the design horizontal load be less than three-percent of the total dead load.

The minimum horizontal load to be allowed for wind on each heavy-duty steel shoring tower having a vertical load carrying capacity exceeding 30-kips per leg shall be the sum of the products of the wind impact area, shape factor, and the applicable wind pressure value for each height zone. The wind impact area is the total projected area of all the elements in the tower face normal to the applied wind. The shape factor for heavy-duty steel shoring towers shall be taken as 2.2. Wind pressure values shall be determined from the following table:

Wind Pressure on Heavy-Duty Steel Shoring Towers

Height Zone (Feet Above Ground)	Wind Pressure Value: Adjacent to Traffic	Wind Pressure Value: At Other Locations
0 to 30	20-psf	15-psf
30 to 50	25-psf	20-psf
50 to 100	30-psf	25-psf
Over 100	35-psf	30-psf

The minimum horizontal load to be allowed for wind on all other types of falsework, including falsework girders and forms supported on heavy-duty steel shoring towers, shall be the sum of the products of the wind impact area and the applicable wind pressure value for each height zone. The wind impact area is the gross projected area of the falsework support system, falsework girders, forms and any unrestrained portion of the permanent Structure, excluding the areas between falsework posts or towers where diagonal bracing is not used. Wind pressure values shall be determined from the following table:

Wind Pressure on All Other Types of Falsework

Height Zone (Feet Above Ground)	Wind Pressure Value: For Members Over and Bents Adjacent to Traffic Openings	Wind Pressure Value: At Other Locations
0 to 30	2.0 Q psf	1.5 Q psf
30 to 50	2.5 Q psf	2.0 Q psf
50 to 100	3.0 Q psf	2.5 Q psf
Over 100	3.5 Q psf	3.0 Q psf

The value of Q in the above tabulation shall be determined as follows:

$Q = 1 + 0.2W$; but Q shall not be more than 10.

Where:

W is the width of the falsework system, in feet, measured normal to the direction of the wind force being considered.

The falsework system shall also be designed so that it will be sufficiently stable to resist overturning prior to the placement of the concrete. The minimum factor of safety against falsework overturning in all directions from the assumed horizontal load for all stages of construction shall be 1.25. If the required resisting moment is less than 1.25 times the overturning moment, the difference shall be resisted by bracing, cable guys, or other means of external support.

Design of falsework shall include the vertical component (whether positive or negative) of bracing loads imposed by the design horizontal load. Design of falsework shall investigate the effects of any horizontal displacement due to stretch of the bracing. This is particularly important when using cable or rod bracing systems.

If the concrete is to be post-tensioned, the falsework shall be designed to support any increased or redistributed loads caused by the prestressing forces.

6-02.3(17)B Allowable Design Stresses and Deflections

The maximum allowable stresses listed in this Section are based on the use of identifiable, undamaged, high-quality materials. Stresses shall be appropriately reduced if lesser quality materials are to be used.

These maximum allowable stresses include all adjustment factors, such as the short term load duration factor. The maximum allowable stresses and deflections used in the design of the falsework and formwork shall be as follows:

Deflection

Deflection resulting from dead load and concrete pressure for exposed visible surfaces, $^{1}/_{360}$ of the span.

Deflection resulting from dead load and concrete pressure for unexposed non-visible surfaces, including the bottom of the deck slab between girders, $^{1}/_{270}$ of the span.

In the foregoing, the span length shall be the center line to center line distance between supports for simple and continuous spans, and from the center line of support to the end of the member for cantilever spans. For plywood supported on members wider than 1½-inches, the span length shall be taken as the clear span plus 1½-inches. Also, dead load shall include the weight of all successive placements of concrete, reinforcing steel, forms and falsework self weight. Only the self weight of falsework girders may be excluded from the calculation of the above deflections provided that the falsework girder deflection is compensated for by the installation of camber strips.

Where successive placements of concrete are to act compositely in the completed Structure, deflection control becomes extremely critical. Maximum deflection of supporting members — $1/500$ of the span for members constructed in several successive placements (such as concrete box girder and concrete T-beam girder Structures) falsework components shall be sized, positioned, and/or supported to minimize progressive increases in deflection of the Structure which would preload the concrete or reinforcing steel before it becomes fully composite.

Timber

Each species and grade of timber/lumber used in constructing falsework and formwork shall be identified in the drawings. The allowable stresses and loads shall not exceed the lesser of stresses and loads given in the table below or factored stresses for designated species and grade in Table 7.3 of the *Timber Construction Manual, Third Edition* by the American Institute of Timber Construction.

Compression perpendicular to the grain reduced to 300-psi for use when moisture content is 19 percent or more (areas exposed to rain, concrete curing water, green lumber).	450-psi
Compression parallel to the grain but not to exceed 1,500-psi.	$\frac{480{,}000\text{-psi}}{(L/d)^2}$
Flexural stress for members with a nominal depth greater than 8-inches.	1,800-psi
Flexural stress psi for members with a nominal depth of 8-inches or less.	1,500-psi
The maximum horizontal shear.	140-psi
AXIAL tension.	1,200-psi
The maximum modulus of elasticity (E) for timber.	1,600,000-psi

Where:

L is the unsupported length; and

d is the least dimension of a square or rectangular column, or the width of a square of equivalent cross-sectional area for round columns.

The allowable stress for compression perpendicular to the grain, and for horizontal shear shall not be increased by any factors such as short duration loading. Additional requirements are found in other parts of Section 6-02.3(17). Criteria for the design of lumber and timber connections are found in Section 6-02.3(17)I.

Plywood for formwork shall be designed in accordance with the methods and stresses allowed in the *APA Design/Construction Guide for Concrete Forming* as published by the American Plywood Association, Tacoma, Washington. As concrete forming is a special application for plywood, wet stresses shall be used and then adjusted for forming conditions such as duration of load, and experience factors. Concrete pour pressures shall be per Section 6-02.3(17)J.

Steel

For identified grades of steel, design stresses shall not exceed those specified in the *Manual of Steel Construction - Allowable Stress Design, Ninth Edition* by the American Institute of Steel Construction, except as follows:

Compression, flexural but not to exceed $0.6F_y$	$\frac{12{,}000{,}000\text{-psi}}{Ld/bt}$
The modulus of elasticity (E) shall be	29,000,000-psi

When the grade of steel cannot be positively identified as with salvaged steel and if rivets are present, design stresses shall not exceed the following:

Yield point f_y	30,000-psi
Tension, axial, and flexural	16,000-psi
Compression, axial except L/r shall not exceed 120	$14{,}150 - 0.37(KL/r)^2$ psi
Shear on gross section of the web of rolled shapes	9,500-psi
Web crippling for rolled shapes	22,500-psi
Compression, flexural but not to exceed 16,000-psi and L/b not greater than 39	$16{,}000 - 5.2(L/b)^2$ psi
The modulus of elasticity (E) shall be	29,000,000-psi

Where:

L is the unsupported length;

d is the least dimension of rectangular columns, or the width of a square of equivalent cross-sectional area for round columns, or the depth of beams;

b is the flange width;

t is the thickness of the compression flange;

r is the radius of gyration of the compression flange about the weak axis of the member; and

F_y is the specified minimum yield stress, psi, for the grade of steel used.

All dimensions are expressed in inches.

6-02.3(17)C Falsework and Formwork at Special Locations

In addition to the minimum requirements specified in Sections 6-02.3(17)A and 6-02.3(17)B, falsework towers or posts supporting beams directly over Roadways or railroads which are open to traffic or the public shall be designed and constructed so that the falsework will be stable if subjected to impact by vehicles. The use of damaged materials, unidentifiable material, salvaged steel or steel with burned holes or questionable weldments shall not be used for falsework described in this section. For the purposes of this Specification the following public or private facilities shall also be considered as "Roadways": pedestrian pathways and other Structures such as bridges, walls, and buildings.

The dimensions of the clear openings to be provided through the falsework for Roadways, railroads, or pedestrian pathways shall be as specified in the Contract.

Falsework posts or shoring tower systems which support members that cross over a Roadway or railroad shall be considered as adjacent to Roadways or railroads. Other falsework posts or shoring towers shall be considered as adjacent to Roadways or railroads only if the following conditions apply:

1. Located in the row of falsework posts or shoring towers nearest to the Roadway or railroad; and
2. Horizontal distance from the traffic side of the falsework to the edge of pavement is less than the total height of the falsework and forms; or
3. The total height of the falsework and forms is greater than the horizontal clear distance between the base of the falsework and a point 10-feet from the centerline of track.

The Contractor shall provide any additional features for the Work needed to ensure that the falsework will be stable for impact by vehicles; providing adequate safeguards, safety devices, protective equipment, and any other needed actions to protect property and the life, health, and safety of the public; and shall comply with the provisions in Section 1-07.23 and Section 6-02.3(17)M. The falsework design at special locations, shall incorporate the minimum requirements detailed in this Section, even if protected by concrete median barrier.

The vertical load used for the design of falsework posts and towers which support the portion of the falsework over openings, shall be the greater of the following:

1. 150-percent of the design load calculated in accordance with Section 6-02.3(17)B, but not including any increased or redistributed loads caused by the post-tensioning forces; or
2. 100-percent of the design load plus the increased or redistributed loads caused by the post-tensioning forces.

Each falsework post or each shoring tower leg adjacent to Roadways or railroads shall consist of either steel with a minimum section modulus about each axis of 9.5-inches cubed or sound timbers with a minimum section modulus about each axis of 250-inches cubed.

Each falsework post or shoring tower leg adjacent to Roadways or railroads shall be mechanically connected to its supporting footing at its base, or otherwise laterally restrained, to withstand a force of not less than 2,000-pounds applied at the base of the post or tower leg in any direction except toward the Roadway or railroad track. Posts or tower legs shall be connected to the falsework cap and stringer by mechanical connections capable of resisting a load in any horizontal direction of not less than 1,000-pounds.

For falsework spans over Roadways and railroads, all falsework stringers shall be mechanically connected to the falsework cap or framing. The mechanical connections shall be capable of resisting a load in any direction, including uplift on the stringer, of not less than 500-pounds. All associated connections shall be installed before traffic is allowed to pass beneath the span.

When timber members are used to brace falsework bents which are located adjacent to Roadways or railroads, all connections shall be bolted through the members using ⅝-inch diameter or larger bolts.

Concrete traffic barrier shall be used to protect all falsework adjacent to traveled Roadways. The falsework shall be located so that falsework footings, mudsills, or piles are at least 2-feet clear of the traffic barrier and all other falsework members shall also be at least 2-feet clear of the traffic barrier. Traffic barrier used to protect falsework shall not be fastened, guyed, or blocked to any falsework but shall be fastened to the pavement according to details shown in the Plans. The installation of concrete traffic barrier shall be completed before falsework erection is begun. The traffic barrier at the falsework shall not be removed until approved by the Engineer. Falsework openings which are provided for the Contractor's own use (not for public use) shall also use concrete traffic barrier to protect the falsework, except the minimum clear distance between the barrier and falsework footings, mudsills, piles, or other falsework members shall be at least 3-inches.

Falsework bents within 20-feet of the center line of a railroad track shall be braced to resist the required horizontal load or 2,000-pounds whichever is greater.

Pedestrian openings through falsework shall be paved or surfaced with full width continuous wood walks which shall be wheel chair accessible and shall be kept clear. Pedestrians shall be protected from falling objects and water falling from construction above. Overhead protection for pedestrians shall extend at least 4-feet beyond the edge of the bridge deck. Plans and details of the overhead protection and pathway shall be submitted with the falsework plans for review and approval. Pedestrian openings through falsework shall be illuminated by temporary lighting, constructed and maintained by the Contractor. The temporary lighting shall be constructed in accordance with local electrical code requirements. The temporary lighting shall be steady burning 60-watt, 120-volt lamps with molded waterproof lamp holders spaced at 25-foot centers maximum. All costs relating to pedestrian pathway paving, wood walks, overhead protection, maintenance, operating costs, and temporary pedestrian lighting shall be incidental to applicable adjacent items of Work.

6-02.3(17)D Falsework Support Systems: Piling, Temporary Concrete Footings, Timber Mudsills, Manufactured Shoring Towers, Caps, and Posts

The Contractor shall support all falsework on either driven piling, temporary concrete footings, or timber mudsills. Temporary concrete footings shall be designed as reinforced concrete which may be either cast in place or precast. All components for a falsework support system shall be sized for the maximum design loads and allowable stresses described in the preceding sections.

The falsework drawings shall include a Superstructure placing diagram showing the concrete placing sequence, direction of placements, and construction joint locations. When a sequence for placing concrete is shown in the Contract Plans or Specifications, no deviation will be permitted.

If the Plans call for piling or foundation shafts to support permanent Structures, the Contractor may not use mudsills or temporary concrete footings for falsework support unless the underlying soil passes the settlement test described in this section.

Piling

When using piling to support the falsework, the Contractor's falsework plans shall specify the minimum required bearing and depth of penetration for the piling. Also, the falsework drawings shall show the maximum horizontal distance that the top of a falsework pile may be pulled in order to position it under its cap. The falsework plans shall show the maximum allowable deviation of the top of the pile, in its final position, from a vertical line through the point of fixity of the pile. The calculations shall account for pile stresses due to combined axial and flexural stress and secondary stresses.

Timber piling (untreated) shall be banded before driving. The following shall be identified in the falsework plans: lengths, minimum tip diameter, and expected diameter at ground line. The Contractor shall comply with the requirements of Sections 9-10.1 and 9-10.1(1). The maximum allowable load for timber piles shall be 45-tons. Steel piling shall be identified in the falsework plans. If steel pipe piling is used, the pipe diameter and wall thickness shall be identified in the falsework plans. Steel piling shall meet the requirements of Section 9-10.5. The formulas in Section 6-05.3(12) shall be used to determine the bearing capacity of the falsework piling. If the Engineer approves, the pile bearing capacity may instead be determined by test loading the piling to twice the falsework design load. The Contractor shall provide the Engineer an opportunity to witness these tests and provide a plan of the test and cross-sections showing the locations and elevations of the proposed tests to the Engineer for approval.

Temporary Concrete Footings and Timber Mudsills

Timber mudsills or temporary concrete footings may be used in place of driven piling, provided tests show that the soil can support twice the falsework design load and that the mudsill or temporary concrete footing will not settle more than ¼-inch when loaded with the design load. The tests shall be done at the falsework site, at the same elevation of the mudsill, and conducted under conditions representative of the actual site conditions. The acceptable tests for various soil types are:

1. **Granular Soil.** The Contractor shall conduct on-site tests according to AASHTO T 235. The Contractor shall provide the Engineer an opportunity to witness these tests and provide a plan of the test and cross-sections showing the locations and elevations of the proposed tests to the Engineer for approval.
2. **Fine Grained or Organic Soil.** The Contractor shall employ a Geotechnical Engineer to investigate the foundation soils and certify in writing that each mudsill or temporary footing will meet the load-settlement requirements described above. The allowable bearing capacities, elevations and locations of specific falsework mudsills shall be listed in the certification. Soils information used to determine the soil bearing capacity and settlement shall be submitted with the written certification to the Engineer for review and approval.

Timber mudsills or temporary concrete footings for falsework shall be designed to carry the loads imposed upon them without exceeding the estimated soil bearing capacity and specified maximum settlement. Where mudsills or temporary footings are used in the vicinity of permanent spread footings, the allowable mudsill bearing pressure shall be less than that of the permanent footings. This is because elevation difference, smaller bearing area, and the lack of surrounding overburden provides a lower bearing capacity than the permanent spread footings. The mudsills shall be designed for bearing capacities at the location that they are to be used. Timber mudsills or temporary concrete footings shall be designed as unyielding foundations under full design loads. The soil pressure bearing values assumed in the design of the falsework (normally not more than 3,000-pounds per sq. ft.) shall be shown in the falsework drawings. The minimum edge distances from the edge of the post or shoring tower leg to the edge or end of the mudsill member shall be shown in the falsework drawings. Timber mudsills and temporary concrete footings shall be designed such that member deflections do not exceed ¼-inch and that member allowable stresses are not exceeded.

Full cross-sectional views of all falsework on timber mudsills or temporary concrete footings to be placed in side slopes or above excavations shall be shown in the falsework drawings. Footings or mudsills which are stepped or placed above an excavation shall have all related geometry and slope stability items identified in the falsework plan. Details and calculations for any shoring system to support the embankment or excavation shall be included.

Mudsills or temporary concrete footings placed in benches in slopes shall be set back from the face of the slope ½ the mudsill or temporary concrete footing width, but not less than 1-foot 0-inches. The bench including the setback shall be level in its narrow dimension. Slopes between benches measured from the top of slope at one bench to the toe of slope at the next bench below shall be no steeper than 1½ horizontal to 1 vertical.

Falsework shall be founded on a solid footing, safe against undermining, protected from softening, and capable of supporting the loads imposed. The preparation of the soil to receive the temporary footing is important to ensure that the falsework does not experience localized settlement that could result in falsework failure. In preparing the soil for a timber mudsill or temporary concrete footing, the Contractor shall:

1. Place it on dry soil that is either undisturbed or compacted to 95-percent of maximum density, as determined by the compaction control tests in Section 2-03.3(14)D performed by the Contractor and submitted to the Engineer for review;
2. Place mudsills or footings level with full contact bearing on the soil with no voids. Place each distribution plate or corbel member between the post or tower leg and the mudsill members such that there is full contact bearing;
3. Place grout or a compacted layer of fine material under the mudsill if it is supported by rock or coarse sand and gravel;
4. Provide the Engineer with a sample of any off-site material to be used under the mudsill;
5. Allow up to 5-working days for the Engineer's approval before using the off-site material; and
6. Provide erosion control measures to protect the soil of the mudsill or footing from undermining and softening.

Anticipated total settlements and incremental settlements of falsework and forms due to successive concrete placements shall be shown in the falsework plans. These shall include falsework footing settlement and joint take-up. Total anticipated settlements shall not exceed 1-inch including joint take-up. When using mudsills, the Contractor shall prepare for the possibility of reshoring with the use of such devices as screw jacks or hydraulic jacks and adjustment of wedge packs. The placing of concrete shall be discontinued if unanticipated settlement occurs, including settlements that deviate more than plus or minus ⅜-inch from those indicated on the approved falsework drawing. Concrete placement shall not resume until corrective measures satisfactory to the Engineer are provided. If satisfactory corrective measures are not provided prior to initial set of the concrete in the affected area, placing of concrete shall be discontinued at a location determined by the Engineer. All unacceptable concrete shall be removed as determined by the Engineer.

Where the maximum leg load exceeds 30-kips, foundations for individual steel towers shall be designed and constructed to provide uniform settlement at each tower leg for all loading conditions.

Bents, Shoring Towers, Piling, Posts, and Caps

Plans for falsework bents or shoring tower systems, including manufactured tower systems shall have plan, cross-section, and elevation view scale drawings showing all geometry. Show in the falsework plans the proximity of falsework to utilities or any nearby Structures including underground Structures. The ground elevation, cross-slopes, relation of stringers to one another, and dimensions to posts or piling shall be shown in the falsework plans. Column, pile, or tower heights shall be indicated. Member sizes, wall thickness and diameter of steel pipe columns or piles shall be shown in the falsework plans. Location of wedges, minimum bearing area and type of wedge material shall be identified in the falsework plans. Bracing size, location, material and all connections shall be described in the falsework plans.

The relationship of the falsework bents or shoring tower systems to the permanent Structure's pier and footing shall be shown. Load paths shall be as direct as possible. Loads shall be applied through the shear centers of all members to avoid torsion and buckling conditions. Where loads cause twisting, biaxial bending, or axial loading with bending, the affected members shall be designed for combined stresses and stability.

Posts or columns shall be constructed plumb with tops and bottoms carefully cut to provide full end bearing. Caps shall be installed at all bents supported by posts or piling unless approved falsework plans specifically permit otherwise. Caps shall be fastened to the piling or posts. The falsework shall be capable of supporting non uniform or localized loading without adverse effect. For example, the loading of cantilevered ends of stringers or caps shall not cause a condition of instability in the adjacent unloaded members.

Timber posts and piling shall be fastened to the caps and mudsills by through-bolted connections, drift pins, or other approved connections. The minimum diameter of round timber posts shall be shown in the falsework plans. Timber caps and timber mudsills shall be checked for crushing from columns or piling under maximum load.

Steel posts and piling shall be welded or bolted to the caps, and shall be bolted or welded to the foundation. Steel members shall be checked for buckling, web yielding, and web crippling.

Wedges shall be used to permit formwork to be taken up and released uniformly. Wedges shall be oak or close-grained Douglas fir. Cedar wedges or shims shall not be used anywhere in a falsework or forming system. Wedges shall be used at the top or bottom of shores, but not at both top and bottom. After the final adjustment of the shore elevation is complete, the wedges shall be fastened securely to the sill or cap beam. Only 1 set of wedges (with 1 optional block) shall be used at 1 location. Screw jacks (or other approved devices) shall be used under arches to allow incremental release of the falsework.

Sand jacks may be used to support falsework and are used for falsework lowering only. Sand jacks shall be constructed of steel with snug fitting steel or concrete pistons. Sand jacks shall be filled with dry sand and the jack protected from moisture throughout its use. They shall be designed and installed in such a way to prevent the unintentional migration or loss of sand. All sand jacks shall be tested per Section 6-02.3(17)G.

When falsework is over or adjacent to Roadways or railroads, all details of the falsework system which contribute to the horizontal stability and resistance to impact shall be installed at the time each element of the falsework is erected and shall remain in place until the falsework is removed. For other requirements see Section 6-02.3(17)C.

Transverse construction joints in the Superstructure shall be supported by falsework at the joint location. The falsework shall be constructed in such a manner that subsequent pours will not produce additional stresses in the concrete already in place.

Manufactured Shoring Tower Systems and Devices

Manufactured proprietary shoring tower systems shall be identified in the falsework plans by make and model and safe working load capacity per leg. The safe working load for shoring tower systems shall be based upon a minimum 2½ to 1 factor of safety.

The safe working load capacity, anticipated deflection (or settlement), make and model shall be identified in the falsework plans for manufactured devices such as: single shores, overhang brackets, support bracket and jack assemblies, friction collars and clamps, hangers, saddles, and sand jacks. The safe working load for shop manufactured devices shall be based on a minimum ultimate strength safety factor of 2 to 1. The safe working load for field fabricated devices and all single shores shall be based on a minimum ultimate strength safety factor of 3 to 1.

The safe working load of all devices shall not be exceeded. The design loads shall be as defined by Section 6-02.3(17)A. The maximum allowable free end deflection of deck overhang brackets under working loads applied shall not exceed $^{3}/_{16}$-inch measured at the edge of the concrete slab regardless of the fact that the deflection may be compensated for by pre-cambering or of setting the elevations high. The Contractor shall comply with all manufacturer's Specifications; including those relating to bolt torque, placing washers under nuts and bolt heads, cleaning and oiling of parts, and the reuse of material. Devices which are deteriorated, bent, warped, or have poorly fitted connections or welds, shall not be installed.

Shoring tower or device capacity as shown in catalogs or brochures published by the manufacturer shall be considered as the maximum load which the shoring is able to safely support under ideal conditions. These maximum values shall be reduced for adverse loading conditions; such as horizontal loads, eccentricity due to unbalanced spans or placing sequence, and uneven foundation settlement.

Depending on load-carrying capacity, steel shoring systems are classified as pipe-frame systems, intermediate strength systems, and heavy-duty systems. The 2 types of pipe-frame shoring base frames in general use are the ladder type and the cross-braced type. In the ladder type, frame rigidity is provided by horizontal struts between the vertical legs, whereas in the cross-braced type rigidity is provided by diagonal cross-bracing between the legs.

Copies of catalog data and/or other technical data shall be furnished with the falsework plans to verify the load-carrying capacity, deflection, and manufacturers installation requirements of any manufactured product or device proposed for use. Upon request by the Engineer, the Contractor shall furnish manufacturer certified test reports and results showing load capacity, deflection, test installation conditions, and identify associated components and hardware for shoring tower systems or other devices. In addition to manufacturer's requirements, the criteria shown in the following sections for manufactured proprietary shoring tower systems and devices shall be complied with when preparing falsework plans, calculations, and installing these shoring tower systems and devices as falsework.

Alternative criteria and/or systems may be approved if a written statement on the manufacturer's letter head, signed by the shoring or device manufacturer (not signed by a material supplier or the Contractor) is submitted to the Engineer for approval and addresses the following:

1. Identity of the specific Contract on which the alternative criteria and/or system will apply;
2. Description of the alternative criteria and/or system;
3. Technical data and test reports;
4. The conditions under which the particular alternative criteria may be followed;
5. That a design based on the alternative criteria will not overstress or over deflect any shoring component or device nor reduce the required safety factor.

In any case where the falsework drawings detail a manufactured product and the manufacturer's safe working load, load versus deflection curves, factor of safety, and installation requirements cannot be found in any catalog, the Engineer may require load testing per Section 6-02.3(17)G to verify the safe working load and deflection characteristics.

Tower leg loads shall not exceed the limiting values under any loading condition or sequence. Frame extensions and any reduced capacity shall be shown in the falsework plans. Screw jacks shall fit tight in the leg assemblies without wobble. Screw jacks shall be plumb and straight. Shoring towers shall be installed plumb, and load distribution beams shall be arranged such that vertical loads are distributed to all legs for all successive concrete placements. There shall be no eccentric loads on shoring tower heads unless the heads have been designed for such loading. Shoring towers shall remain square or rectangular in plan view and shall not be skewed. There shall be no interchanging of parts from one manufactured shoring system to another. Bent or faulty components shall not be used.

For manufactured shoring towers that allow ganging of frames, the number of ganged frames shall be limited to 1 frame per opposing side of a tower, and the total number of legs per ganged tower shall not exceed 8 legs. Ganged frames shall be installed per the manufacturer's published standards using the manufacturer's components. Other gang arrangements shall not be used.

For manufactured steel shoring tower systems, the Contractor shall have bracing designed and installed for horizontal loads and falsework overturning per Section 6-02.3(17)A. Minimum bracing criteria and allowable leg loads are described in the following paragraphs.

All shoring tower systems and bracing shall be thoroughly inspected by the Contractor for plumb vertical support members, secure connections, and straight bracing members immediately prior to, at intervals during, and immediately after every concrete placement. For manufactured shoring tower systems, the maximum allowable deviation from the vertical is ⅛-inch in 3-feet. If this tolerance is exceeded, concrete shall not be placed until adjustments have brought the shoring towers within the acceptable tolerance.

Cross-Braced Type Base Frames

The maximum allowable load per leg for cross-braced type base frame shoring is limited by the height of the extension frame and the type of screw jack (swivel or fixed head) used at the top of the frame. The maximum load on 1 leg of a frame shall not exceed 4 times the load on the other leg under any given loading condition or sequence. The maximum load on 1 of the 2 frames making up a tower shall not exceed 4 times the load on the opposite frame under any given loading condition or sequence. If swivel-head screw jacks are used, the allowable leg loads shall not exceed that shown in the following table:

Maximum Allowable Leg Load in Pounds				
Extension Frame Height	**2′-0"**	**3′-0"**	**4′-0"**	**5′-0"**
Screw height 12" or less	11,000	11,000	10,000	9,400
Screw height exceeds 12"	8,200	8,200	8,000	7,800

If fixed-head screw jacks are used at the top of the extension frame, the maximum allowable load per leg shall be 11,000-pounds for all extension frame heights up to 5-feet with screw jack height extensions of 12-inches or less. Fixed-head screw jacks exceeding 12-inches shall use the values in the table above. Screw jack extensions shall not exceed the manufacturer's published recommendations. Extension frames shall be braced. Side cross-braces are required for extension heights up to 2-feet 0-inches. Both side and end cross-braces are required from over 2-feet 0-inches to 5-feet 0-inches extension heights.

Supplemental bracing shall be installed on shoring towers 20-feet or more in height and shall connect rows of towers to each other so rows of frames are continuously cross-braced in 1 plane. Supplemental bracing shall be installed as follows:

1. In the transverse direction (the direction parallel to the frame) 1 horizontal brace and 1 diagonal brace shall be attached to each tower face, for every 3 frames of shoring height, including an extension frame if used. The lowest horizontal brace shall be located near the top of the third tower frame, and any additional horizontal braces spaced no farther than 3 frames apart. The diagonal braces shall be located on opposite tower faces, and shall run in opposite directions across the plane of the tower row.
2. In the longitudinal direction (the direction perpendicular to the frames), when shoring height is 4 frames or more, a horizontal brace shall be installed on 1 face of each tower, with the lowest brace located no higher than the top of the fourth frame and any additional horizontal braces spaced no farther than 4 frames apart. When shoring height is 6 frames or more, diagonal cross-bracing shall be installed in the longitudinal direction similar to the transverse direction.
3. When Roadway grade, soffit profile, or superelevation exceeds 4-percent slope for any height of shoring tower, a continuous brace parallel to the slope shall be attached to each frame extension or screw jack of the tower within 6-inches of the top. These braces shall be in addition to bracing previously described.

The bracing shall be fastened securely to each frame leg and shall be located within 6-inches of the frame member intersections. The ends of diagonal braces shall not be attached to shoring frames at locations where towers have little or no load. Diagonal brace ends shall be attached to tower frames near the top and bottom at locations where significant gravity load is maintained throughout all construction sequences, such as directly below box girder outside webs, thus precluding lift-off due to the vertical component of the brace reaction. Supplemental bracing shall be shown in the falsework drawings. The connection details, including the method of connection and exact location of the connecting devices, shall be in accordance with the manufacturer's recommendations and shall be shown in the falsework drawings.

Ladder Type Base Frames

Ladder type base frame shoring shall be limited to the following maximum loads and conditions, regardless of any conflicting information which may be found in manufacturer's catalogs or brochures:

1. If the shoring system consists of a single tier of braced base frames, leg loads shall not exceed 10,000-pounds.
2. If the shoring system consists of 2 or 3 tiers of base frames, leg loads shall not exceed 7,500-pounds.

3. If an extension staff is used, the maximum allowable leg load shall be reduced to 6,000-pounds.
4. The maximum load on 1 leg of a frame shall not exceed 4 times the load on the other leg under any given loading condition or sequence. The maximum load on 1 of the 2 frames making up a tower shall not exceed 4 times the load on the opposite frame under any given loading condition or sequence.

Maximum allowable leg loads as shown above shall apply when fixed-head screw jacks are used, or when swivel-head jacks are used at either the top or bottom of the tower. A screw jack extension shall not exceed 12-inches. Swivel-head screw jacks shall not be used at both the top and bottom of ladder-type frames. For any combination of ladder-type base frames or base frames with staff extensions, the total height of the shoring shall not exceed 20-feet, including screw jack extensions.

When Roadway grade, soffit profile, or superelevation exceeds 4-percent slope for heights of shoring towers 20-feet or less, a continuous brace parallel to the slope shall be attached to each staff extension or screw jack of the tower within 6-inches of the top. These braces shall be attached per conditions described previously for cross-braced frames.

Intermediate Strength Shoring

Steel shoring, consisting of cross-braced tubular members capable of carrying up to 25-kips per tower leg, is considered intermediate strength shoring. The use of a 25-kip type falsework shoring system shall meet the following conditions and limitations:

1. If swivel-head screw jacks are used at either the top or bottom of the tower, the maximum allowable load shall be reduced to 20-kips per tower leg.
2. The screw-jack extensions shall not exceed 14-inches.
3. Extension frames shall be braced. Side cross-braces are required for all extension-frame heights. In addition, end cross-braces (braces across the face of the extension frame) shall be provided for extension frame heights of 3-feet or more.
4. The maximum load on 1 leg of a frame, or on 1 frame of a tower, shall not exceed 4 times the load on the opposite leg or frame under any given loading condition or sequence.
5. Shoring towers 20-feet or more in height shall have supplemental bracing installed in accordance with the criteria for bracing "Cross-braced Type Base Frames," except that no supplemental bracing will be required in the longitudinal direction (the direction perpendicular to the frame).
6. When Roadway grade, soffit profile, or superelevation exceeds 4-percent slope for any height of shoring tower, a continuous brace parallel to the slope shall be attached to each frame extension or screw jack of the tower within 6-inches of the top. These braces shall be in addition to bracing required in item 5.

The use of 25-kip shoring, when designed and erected in conformance with the above criteria, is acceptable for tower heights up to 5 frames plus a fully-extended extension frame plus the maximum allowable screw-jack adjustment. For any proposed use exceeding this limiting height, the Contractor shall furnish a statement signed by the shoring manufacturer covering the specific installation. The statement shall provide assurance that the shoring will carry the loads to be imposed without overstressing any shoring component or reducing the required safety factor.

Heavy-Duty Shoring Systems

Shoring capable of carrying up to 100-kips per tower leg is considered heavy duty shoring. The following criteria applies to these systems.

If tower legs, including any extension unit, are utilized as single-post shores braced in 1 direction only, the shores shall be analyzed as individual steel columns.

If the total height of the shoring does not exceed the height of a single tower unit, including any extension unit, and if both the base and extension units are fully braced in both directions in accordance with the manufacturer's recommendations, individual tower legs may be considered as capable of carrying the safe working load recommended by the manufacturer without regard to the load on adjacent legs.

If the shoring consists of 2 or more units stacked 1 above the other, either with or without an extension unit, the differential leg loading within a given tower unit shall not exceed the following limitations:

Differential Leg Loading

Maximum load on any leg in the tower unit	Maximum to Minimum load ratio
10-kips or less	10 to 1
10-kips to 50-kips	6 to 1
50-kips to 75-kips	5 to 1
75-kips or more	4 to 1

A complete stress analysis of steel beams used as continuous caps over 2 or more tower units shall be performed to determine the effect of continuity on tower leg loads. Resulting moment shear shall be added to or subtracted from the simple beam reaction to obtain the actual leg load and may produce a significant load differential.

Heavy-duty shoring shall be diagonally braced or otherwise externally supported at the top unless the towers are stable against overturning as defined in Section 6-02.3(17)A. When designing external bracing, including cable bracing, attention shall be given to the bracing connection to the falsework. Connections shall be designed to transfer horizontal and vertical forces from the falsework to the bracing system without overstressing any tower component. All external bracing, attachment locations, and connection details shall be shown in the falsework plans.

6-02.3(17)E Stringers, Beams, Joists, Roadway Slab Support, and Deck Overhangs

All stringers, beams, joists, and roadway slab support shall be designed for the design loads, deflections, and allowable stresses described in the preceding Sections 6-02.3(17)A, B, and C and for the following conditions.

At points of support, stringers, beams, joists, and trusses shall be restrained against rotation about their longitudinal axis. The effect of biaxial bending shall be investigated in all cases where falsework beams are not set plumb and the Structure cross-slope exceeds 3-percent.

For box girder and T-beam bridges, the centerline of falsework beams or stringers shall be located within 2-feet of the bridge girder stems and preferably directly under the stems or webs. Stringers supporting formwork for concrete box girder and T-beam slab overhangs shall be stiff enough so that the differential deflection due to the roadway slab pour is no more than $^{3}/_{16}$-inch between the outside edge of the roadway slab and the exterior web even if camber strips can compensate for the deflection.

Friction shall not be relied upon for lateral stability of beams or stringers. If the compression flange of a beam is not laterally restrained, the allowable bending stress shall be reduced to prevent flange buckling. If flange restraint is provided and since it is impossible to predict the direction in which a compression flange will buckle, positive restraint shall be provided in both directions. Flange restraint shall be designed for a minimum load of 2-percent of the calculated compression force in the beam flange at the point under consideration.

Camber strips shall be used to compensate for falsework take-up and deflection, vertical alignment, and the anticipated Structure dead load deflection shown in the camber diagram in the Contract Plans. Camber is the adjustment to the profile of a load-supporting beam or stringer so that the completed Structure will have the lines and grades shown in the Plans. The dead load camber diagram shown in the Contract Plans is the predicted Structure dead load deflection due to self mass. This dead load camber shall be increased by:

1. Amount of anticipated falsework take up;
2. Anticipated deflection of the falsework beam or stringer under the actual load imposed; and
3. Any vertical curve compensation.

Camber strips shall be fastened by nailing to the top of wood members, or by clamping or banding in the case of steel members. Camber strips shall have sufficient contact bearing area to prevent crushing under total load. As a general rule, camber strips are not required unless the total camber adjustment exceeds ¼-inch for exterior falsework stringers and ½-inch for interior stringers.

On concrete box girder Structures, the forms supporting the roadway slab shall rest on ledgers or similar supports and shall not be supported from the bottom slab except as provided below. The form supports shall be fastened within 18-inches of the top of the web walls, producing a clear span between web walls. The roadway slab forms may be supported or posted from the bottom slab if the following conditions are met:

1. Permanent access, shown in the Contract Plans, is provided to the cells, and the centerline to centerline distance between web walls is greater than 10-feet;
2. Falsework stringers designed for total load, stresses and deflections per Section 6-02.3(17)A and B are located directly below each row of posts;
3. Posts have adequate lateral restraint; and
4. All forms (including the roadway deck forms), posts, and bracing are completely removed.

The falsework and forms on concrete box girder Structures supporting a sloping web and deck overhang shall consist of a lateral support system which is designed to resist all rotational forces acting on the stem, including those caused by the placement of deck slab concrete, roadway deck formwork mass, finishing machine, and other live loads. Stem reinforcing steel shall not be stressed by the construction of the roadway deck slab placement. Overhang brackets shall not be used for the support of roadway slab forms from sloping web concrete box girder bridges.

Deck slab forms between girders or webs shall be constructed such that there is no differential settlement relative to the girders. The support systems for form panels supporting concrete deck slabs and overhangs on girder bridges (such as steel plate girders and prestressed girders) shall be designed as falsework. Falsework supporting deck slabs and overhangs on girder bridges shall be supported directly by the girders so that there will be no differential settlement between the girders and the deck forms during placement of deck concrete.

6-02.3(17)F Bracing

All falsework bracing systems shall be designed to resist the horizontal design load in all directions with the falsework in either the loaded or unloaded condition. All bracing, connection details, specific locations of connections, and hardware used shall be shown in the falsework plans. Falsework diagonal bracing shall be thoroughly analyzed with particular attention given to the connections. The allowable stresses in the diagonal braces may be controlled by the joint strength or the compression stability of the diagonal. Timber bracing for timber falsework bents shall have connections designed per Section 6-02.3(17)I. Any damaged cross-bracing, such as split timber members shall be replaced. Steel strapping shall avoid making sharp angles or right-angle bends. A means of preventing accidental loss of tension shall be provided for steel strapping. See Sections 6-02.3(17)A, B, and C for design loads and allowable stresses.

Bracing shall not be attached to concrete traffic barrier, guardrail posts, or guardrail.

To prevent falsework beam or stringer compression flange buckling, cross-bracing members and connections shall be designed to carry tension as well as compression. All components, connection details and specific locations shall be shown in the falsework plans. Bracing, blocking, struts, and ties required for positive lateral restraint of beam flanges shall be installed at right angles to the beam in plan view. If possible, bracing in adjacent bays shall be set in the same transverse plane. However, if because of skew or other considerations, it is necessary to offset the bracing in adjacent bays, the offset distance shall not exceed twice the depth of the beam.

All falsework and bracing shall be inspected by the Contractor for plumbness of vertical support members, secure connections, tight cables, and straight bracing members immediately prior to, during, and immediately after every concrete placement.

Bracing shall be provided to withstand all imposed loads during erection of the falsework and all phases of construction for falsework adjacent to any Roadway, sidewalk, or railroad track which is open to the public. All details of the falsework system which contribute to horizontal stability and resistance to impact, including the bolts in bracing, shall be installed at the time each element of the falsework is erected and shall remain in place until the falsework is removed. The falsework plans shall show provisions for any supplemental bracing or methods to be used to conform to this requirement during each phase of erection and removal. Wind loads shall be included in the design of such bracing or methods. Loads, connections, and materials for falsework adjacent to Roadways, shall also be in accordance with Section 6-02.3(17)C.

Cable or Tension Bracing Systems

When cables, wire rope, steel rod, or other types of tension bracing members are used as external bracing to resist horizontal forces, or as temporary bracing to support bents while falsework is being erected or removed adjacent to traffic, all elements of the bracing system shall be shown in the falsework plans. Bracing shall not be attached to concrete traffic barrier, guardrail posts, or guardrail. Any damaged bracing, such as frayed and kinked guying systems shall be replaced. Wire rope shall avoid making sharp angles or right-angle bends and a means of preventing accidental loss of tension shall be provided. The following information shall be submitted to the Engineer for approval:

1. Cable diameter, rod, or tension member size, and allowable working load.
2. Location and method of attaching the cable, rod, or tension member to the falsework. The connecting device shall be designed to transfer both horizontal and vertical forces to the cable without overstressing any falsework component.
3. The type of cable connectors or fastening devices (such as U-bolt clips, plate clamps, etc.) to be used and the efficiency factor for each type. If cables are to be spliced, the splicing method shall be shown.
4. Method of tightening cables, rods, or tension members after installation if tightening is necessary to ensure their effectiveness. Method of preventing accidental loosening.
5. Anchorage details, including the size and mass of concrete anchor blocks, the assumed coefficient of friction for surface anchorages, and the assumed lateral soil bearing capacity for buried anchorages.
6. Method of pre-stretching or preloading cable or tension members.
7. Determination of the potential stretch or elongation of the tension member under the design load and if the resulting lateral deflection will cause excessive secondary stresses in the falsework.

Copies of manufacturer's catalog or brochure showing technical data pertaining to the type of cable to be used shall be furnished with the falsework plans. Technical data shall include the cable diameter, the number of strands and the number of wires per strand, ultimate breaking strength or recommended safe working strength, and any other information as may be needed to identify the cable.

In the absence of sufficient technical data to identify the cable, or if it is old and obviously worn, the Contractor shall perform cable breaking tests to establish the safe working load for each reel of cable furnished. For static guy cable the minimum factor of safety shall be 3 to 1. The Contractor shall provide the Engineer an opportunity to witness these tests.

When cable bracing is used to prevent the overturning of heavy-duty shoring, attention shall be given to the connections by which forces are transferred from the shoring to the cables. Cable restraint shall be designed to act through the cap system to prevent the inadvertent application of forces which the shoring is not designed to withstand. Cables shall not be attached to any tower component.

Cable splices made by lapping and clipping with "Crosby" type clamps shall not be used. Other splicing methods may be used; however, at each location where the cable is spliced, cable strength shall be verified by a load test.

When cables are used as external bracing to resist overturning of a falsework system, the horizontal load to be carried by the cables shall be calculated as follows:

1. When used with heavy-duty shoring systems, cables shall be designed to resist the difference between 1.25 times the total overturning moment and the resistance to overturning provided by the individual falsework towers.
2. When used with pipe-frame shoring systems where supplemental bracing is required, cables shall be designed to resist the difference between 1.25 times the total overturning moment and the resistance to overturning provided by the shoring system as a whole.
3. When used as external bracing to prevent overturning of all other types of falsework, including temporary support during erection and removal of falsework at traffic openings, cables shall be designed to resist 1.25 times the total overturning moment.

The maximum allowable cable design load shall be determined using the following criteria:

1. If the cable is new, or is in uniformly good condition, and if it can be identified by reference to a manufacturer's catalog or other technical publication, the allowable load shall be the ultimate strength of the cable as specified by the manufacturer, multiplied by the efficiency of the cable connector, and divided by a safety factor of 3 (i.e., safe working load = breaking strength x connector efficiency/safety factor).
2. If the cable is used but still in serviceable condition, or is new or nearly new but cannot be found in a manufacturer's catalog, the Contractor shall perform load breaking tests. In this case, the cable design load shall not exceed the breaking strength, as determined by the load test, multiplied by the connector efficiency factor, and divided by a safety factor of 3.
3. If the cable is used and still in serviceable condition, or is a new or nearly new cable which cannot be identified, and if load breaking tests are not performed, the cable design load shall not exceed the safe working load shown in the wire rope capacities table multiplied by the cable connector efficiency.

   Cable connectors shall be designed in accordance with criteria shown in the following tables "Efficiency of Wire Rope Connections" and "Applying Wire Rope Clips." Cable safe working loads are provided in table "Wire Rope Capacities."

Efficiency of Wire Rope Connections
(As compared to Safe Loads on Wire Rope)

Type of Connection	Connector Efficiency
Wire Rope	100%
Sockets — Zink Type	100%
Wedge Sockets	70%
Clips — Crosby Type With Thimble	80%
Knot and Clip (Contractors Knot)	50%
Plate Clamp — 3 Bolt Type With Thimble	80%
Spliced Eye and Thimble:	
¼" and smaller	100%
⅜" to ¾"	95%
⅞" to 1"	88%
1⅛" to 1½"	82%
1⅝" to 2"	75%
2⅛" and larger	70%

Wire Rope Capacities Safe Load in Pounds for New Plow Steel Hoisting Rope 6-Strands of 19-Wires, Hemp Center (Safety Factor of 6)		
Diameter Inches	Weight Lbs./Ft.	Safe Load Lbs.
¼	0.10	1,050
5⁄16	0.16	1,500
⅜	0.23	2,250
7⁄16	0.31	3,070
½	0.40	4,030
9⁄16	0.51	4,840
⅝	0.63	6,330
¾	0.95	7,930
⅞	1.29	10,730
1	1.60	15,000
1⅛	2.03	18,600
1¼	2.50	23,000
1⅜	3.03	25,900
1½	3.60	30,700
1⅝	4.23	35,700
1¾	4.90	41,300

Applying Wire Rope Clips

The only correct method of attaching U-bolt wire rope clips to rope ends is to place the base (saddle) of the clip against the live end of the rope, while the "U" of the bolt presses against the dead end.

The clips are usually spaced about 6 rope diameters apart to give adequate holding power. A wire-rope thimble shall be used in the loop eye to prevent kinking when wire rope clips are used. The correct number of clips for safe application, and spacing distances, are shown below:

Number of Clips and Spacing for Safe Application			
	Number of Clips		Minimum
Improved Plow Steel Rope Diameter Inches	Drop Forged	Other Material	Spacing (Inches)
⅜	2	3	3
½	3	4	3½
⅝	3	4	4
¾	4	5	4½
⅞	4	5	5¼
1	5	6	6
1⅛	6	6	6¾
1¼	6	7	7½
1⅜	7	7	8¼
1½	7	8	9

Anchor Blocks

Concrete anchor blocks and connections used to resist forces from external bracing shall be shown in the falsework plans. Concrete anchor blocks shall be proportioned to resist both sliding and overturning. When designing anchor block stability, the mass of the anchor block shall be reduced by the vertical component of the cable or brace tension to obtain the net or effective mass to be used in the anchorage computations. The coefficient of friction assumed in the design shall not exceed the following:

	Friction Coefficient
Anchor block set on sand	0.40
Anchor block set on clay	0.50
Anchor block set on gravel	0.60
Anchor block set on pavement	0.60

Note: Multiply the friction coefficient by 0.67 if it is likely the supporting material is wet or will become wet during the construction period.

The method of connecting the cable or brace to the anchor block is part of the anchor block design. The connection shall be designed to resist both horizontal and vertical forces.

Temporary Bracing for Bridge Girders

Bridge girders (such as steel plate girders and prestressed girders) shall be braced and tied to resist forces that would cause rotation or torsion in the girders caused by the placing of concrete for diaphragms or the deck. These conditions also apply to bridge widenings and stage constructed bridges where construction sequences can cause rotation or torsion in the girders. Falsework support brackets or braces shall not be welded to structural steel members or reinforcing steel.

On prestressed girder spans, the Contractor shall install cross-bracing between girders at each end and midspan to prevent lateral movement or rotation. This bracing shall be placed prior to the release of the girders from the erection equipment. The bracing shall not be removed until the diaphragms or the deck have been placed and cured for a minimum of 24-hours.

When deck overhang or the distance from the centerline of the exterior girder (or outside girder of a staged construction) to the near edge of the roadway slab on a prestressed girder span exceeds the distances listed in the table below, the Contractor shall provide extra bracing for the exterior girder at the midpoint between diaphragms (or at more frequent intervals). This bracing shall include: (1) a cross-tie connecting the top flange of each exterior girder with its counterpart on the other side, and (2) braces between the bottom flanges and top flanges of all girders.

Girder Series	Distance in Inches
W42G	30
W50G	42
W58G	63
W74G	66
Prestressed concrete tub girders with webs with flanges	30
WF42G, WF50G, WF58G, WF74G, W83G, and W95G	70
W32BTG, W38BTG, and W62BTG	70
WF74PTG, W83PTG, and W95PTG	70

If a concrete finishing machine is supported at the outside edge of the slab, the Contractor shall account for its added mass in the design of bracing.

Roadway deck forming systems may require bracing or ties between girders for the girder to adequately support the form loading. When braces, struts, or ties are required, they shall be designed and detailed by the Contractor and shall be shown in the falsework/formwork plans submitted to the Engineer for approval. These braces, struts, and ties shall be furnished and installed by the Contractor at no additional cost to the Contracting Agency.

6-02.3(17)G Testing Falsework Devices

The Contractor shall establish the load capacity and deflection (or settlement) of all friction collars and clamps, brackets, hangers, saddles, sand jacks, and similar devices utilizing a recognized independent testing Laboratory approved by the Engineer. Laboratory tests shall use the same materials and design that will be used on the project. Test loads shall be applied to the device in the same manner that the device will experience loading on the project. Any bolts or threaded rods used with the device shall be identified as to diameter, length, type, grade, and torque. Any wedges, blocks, or shims used with the device on the project shall also be tested with the device. Any adjustable jack system used as a part of a device shall be tested with the device and shall have its maximum safe working extended height identified. Devices shall not be tested in contact with the permanent Structure. Independent members with the same properties as the permanent Structure shall be used to test device connections.

At least 14-days prior to the test, the Contractor shall submit a test procedure and scale drawing for the Engineer’s approval showing how the device will be tested and how data will be collected. The Contractor shall provide the Engineer an opportunity to witness these tests.

The approved independent testing Laboratory shall provide a certified test report which shall be signed and dated. The test report shall clearly identify the device tested including trademarks and model numbers; identify all parts and materials used, including grade of steel, or lumber, member section dimensions; location, size, and the maximum tested extended height of any adjustable jacks; indicate condition of materials used in the device; indicate the size, length and location of all welds; indicate how much torque was used with all bolts and threaded rods. The report shall describe how the device was tested, report the results of the test, provide a scale drawing of the device showing the location(s) of where deflections or settlements were measured, and show where load was applied. Deflections or settlements shall be measured at load increments and the results shall be clearly graphed and labeled. Prior to installation of falsework devices named in this section, the Contractor shall submit the certified test reports to the Engineer for review and approval.

The safe working load for shop manufactured devices named in this section shall be derived by dividing the ultimate strength by a safety factor of 2.0. The safe working load for field fabricated or field modified devices (including the use of timber blocks or wedges with the device) shall be determined by dividing the ultimate strength by a safety factor of 3.0. Working load shall include masses of all successive concrete placements, falsework, forms, all load transfer that takes place during post-tensioning, and any live loads; such as workers, Roadway finishing machines, and concrete delivery systems. The maximum allowable free end deflection of deck overhang brackets with combined dead and live working loads applied shall be $^{3}/_{16}$-inch even though deflection may be compensated for by pre-cambering or setting the elevations high. The Contractor shall comply with all manufacturer's Specifications; including those relating to bolt torque, cleaning and oiling of parts, and the reuse of material. Devices which are deteriorated, bent, warped or have poorly fitted connections or welds, shall not be installed.

6-02.3(17)H Formwork Accessories

Formwork accessories such as form ties, form anchors, form hangers, anchoring inserts, and similar hardware shall be specifically identified in the formwork plans including the name and size of the hardware, manufacturer, safe working load, and factor of safety. The grade of steel shall also be indicated for threaded rods, coil rods, and similar hardware. Wire form ties and taper ties shall not be used. Welding or clamping formwork accessories to Contract Plan reinforcing steel will not be allowed. Driven types of anchorages for fastening forms or form supports to concrete, and Contractor fabricated "J" hooks shall not be used. Field drilling of holes in prestressed girders is not allowed.

The following table from ACI 347R-88 provides minimum safety factors for formwork accessories. The hardware proposed shall meet these minimum ultimate strength requirements or the manufacturer's minimum requirements, whichever provides the greater factor of safety. The Contractor shall attach copies of the manufacturer's catalog cuts and/or test data of hardware proposed, to the formwork plans and submit the falsework and formwork plans and calculations for review and approval per Section 6-02.3(16). In situations where catalog cuts and/or test data are not available, testing shall be performed in accordance with Section 6-02.3(17)G.

Minimum Safety Factors of Formwork Accessories*

Accessory	Safety Factor	Type of Construction
Form Tie	2.0	All applications.
Form Anchor	2.0	Formwork supporting form mass and concrete pressures only.
Form Anchor	3.0	Formwork supporting masses of forms, concrete, construction live loads, and impact.
Form Hangers	2.0	All applications.
Anchoring Inserts	2.0	Placed in previous opposing concrete placement to act as an anchor for form tie.

*Safety factors are based on ultimate strength of the formwork accessory.

The bearing area of external holding devices shall be adequate to prevent excessive bearing stress on form lumber. Form ties and form hangers shall be arranged symmetrically on the supporting members to minimize twisting or rotation of the members. Form tie elongation shall not exceed the allowable deflection of the wale or member that it supports. Inserts, bolts, coil rods, and other fasteners shall be analyzed and designed for appropriately combined bending, shear, torsion, and tension stresses. The formwork shall not be attached to Contract Plan rebar or rebar cages. However, the Contractor may install additional reinforcing steel for formwork anchorage.

Frictional resistance shall not be considered as contributing to the stability of any connection or connecting device, except those designed as friction connectors such as U-bolt friction-type connectors.

Form anchors and anchoring inserts shall be designed considering concrete strength at time of loading, available embedment, location in the member, and any other factors affecting their working strength, and shall be installed in concrete per the manufacturer's published requirements. Form anchors and anchoring inserts embedded in previous concrete placements shall not be loaded until the concrete has reached the required design strength. The required design strength of concrete for loading of an anchor shall be shown in the formwork drawing if it is assumed that the anchor will be loaded before the concrete has reached its 28-day strength.

Installation of permanent concrete inserts, such as form ties hangers, or embedded anchor assemblies, shall permit removal of all metal to at least ½-inch below the concrete surface. Holes shall be patched in accordance with Section 6-02.3(14). During removal of the outer unit, the bond between the concrete and the inner unit or rod shall not be broken.

6-02.3(17)I Timber Connections

Timber connections shall be designed in accordance with the methods, stresses, and loads allowed in the Timber Construction Manual, Third Edition by the American Institute of Timber Construction (AITC). Timber falsework and formwork connections shall be designed using wet condition stresses for all installations West of the Cascade Range crest line and by criteria provided in the following sections. Frictional resistance shall not be considered as contributing to the stability of any timber connection.

Bolted Connections

Tabulated values in the AITC Timber Construction Manual-Third Edition are based on square posts. For a round post or pile, the main member thickness shall be the side of a square post having the same cross-sectional area as the round post used.

The AITC Table 6.20 for Douglas Fir-Larch bolt Group 3 and for Hem-Fir bolt Group 8 show design values for bolts to be used when the load is applied either parallel or perpendicular to the direction of the wood grain. When the load is applied at an angle to the grain, as is the case with falsework bracing, the design value for the main member shall be obtained from the Hankinson formula shown in the AITC manual.

Design values in the AITC Table 6.20 apply only to 3-member joints (bolt in double-shear) in which the side members are each ½ the thickness of the main member. This joint configuration is not typical of bridge falsework where side members are usually much smaller than main members. For 2 member joints (single shear bolt condition), the AITC Table 6.20 values shall be adjusted by a single shear load factor as follows:

1. 0.75 for installations East of the Cascade Range crest line, except as shown in item 3 below;
2. 0.50 for installations West of the Cascade Range crest line; and
3. 0.50 for load acting at an angle to the bolt axis, as is the case with longitudinal bracing when falsework bents are skewed.

Except for connections in falsework adjacent to or over railroads or Roadways, threaded rods and coil rods may be used in place of bolts of the same diameter with no reduction in the tabulated values. At openings for Roadways and railroads, all connections shall be bolted using ⅝-inch diameter or larger through bolts.

Bolt holes shall be a minimum $\frac{1}{32}$-inch to a maximum ⅛-inch larger than the bolt diameter. A washer not less than a standard cut washer shall be installed between the wood and the bolt head and between the wood and the nut to distribute the bearing stress under the bolt head and nut and to avoid crushing the fibers. In lieu of standard cut washers, metal plates or straps with dimensions at least equal to that of a standard cut washer may be substituted.

When steel bars or shapes are used as diagonal bracing, the tabulated design values shown in AITC Table 6.20 for the main members loaded parallel to grain (P value) are increased 75-percent for joints made with bolts ½-inch or less in diameter, 25-percent for joints made with bolts 1½-inch in diameter, and proportionally for intermediate diameters. No increase in the tabulated values is allowed for perpendicular-to-grain loading (Q value).

Clearance requirements for end, edge, and bolt spacing distance shall be as shown below. All distances are measured from the end or side of the wood member to the center of the bolt hole. For members which are subject to load reversals the larger controlling distances shall be used for design. For parallel-to-grain loading, the minimum distances for full design load:

1. In tension, minimum end distance shall be 7 times the bolt diameter;
2. In compression, minimum end distance shall be 4 times the bolt diameter; and
3. In tension or compression, the minimum edge distance shall be 1.5 times the bolt diameter.

For perpendicular-to-grain loading, the minimum distance for full design load:

1. Minimum end distance shall be 4 times the bolt diameter;
2. Edge distance toward which the load is acting shall be at least 4 times the bolt diameter; and
3. Distance on the opposite edge shall be at least 1.5 bolt diameters.

Minimum clearance (spacing) between adjacent bolts in a row shall be 4 times the bolt diameter, measured center-to-center of the bolt holes.

When more than 2 bolts are used in a line parallel to the axis of the side member, additional requirements shall be followed as shown in the AITC manual.

Lag Screw Connections

Design values for lag screws subject to withdrawal loading are found in AITC Table 6.27. Values for wood having a specific gravity of 0.51 for Douglas Fir-Larch or 0.42 for Hem-Fir shall be assumed when using the table. The withdrawal values are in pounds per inch of penetration of the threaded part of the lag screw into the side grain of the member holding the point, with the axis of the screw perpendicular to that member. The maximum load on a given screw shall not exceed the allowable tensile strength of the screw at the root section.

AITC recommends against subjecting lag screws to end-grain withdrawal loading. However, if this condition cannot be avoided, the design value shall be 75-percent of the corresponding value for withdrawal from the side grain.

Values in the Group II wood species column shall be used for Douglas Fir-Larch and the Group III wood species column shall be used for Hem-Fir. When the load is applied at an angle to the grain, as is the case with falsework bracing, the design value shall be obtained from the Hankinson formula shown in the AITC manual.

When lag screws are subjected to a combined lateral and withdrawal loading, as would be the case with longitudinal bracing when the falsework bents are skewed, the effect of the lateral and withdrawal forces shall be determined separately. The withdrawal component of the applied load shall not exceed the allowable value in withdrawal. The lateral component of the applied load shall not exceed the allowable lateral load value.

Lag screws shall be inserted in lead holes as follows:

1. The clearance hole for the shank shall have the same diameter as the shank, and the same depth of penetration as the length of unthreaded shank;
2. The lead hole for the threaded portion shall have a diameter equal to 60 to 75-percent of the shank diameter and a length equal to at least the length of the threaded portion. The larger percentile figure in each range shall apply to screws of the greater diameters used in Group II wood species;
3. The threaded portion of the screw shall be inserted in its lead hole by turning with a wrench, not by driving with a hammer; and
4. To facilitate insertion, soap or other lubricant shall be used on the screws or in the lead hole.

Drift Pin and Drift Bolt Connections

When drift pins or drift bolts are used, the required length and penetration shall be determined using the following criteria. The lateral load-carrying capacity of drift pins and drift bolts driven into the side grain of a wood member shall be limited to 75-percent of the design values for a common bolt of the same diameter and length in the main member. For drift pin connections, the pin penetration into the connected members shall be increased to compensate for the absence of a bolt head and nut. For drift bolts or pins driven into the end grain of a member, the lateral load-carrying capacity shall be limited to 60-percent of the allowable side grain load (perpendicular to grain value) for an equal diameter bolt with nut. To develop this allowable load the drift bolt or pin shall penetrate at least 12-diameters into the end grain. To fully develop the allowable load of the drift bolts or pins, they shall be driven into predrilled holes, $^1/_{16}$-inch less in diameter than the drift pin or bolt diameter.

The criteria shown in the AITC *Timber Construction Manual-Third Edition* shall apply to drift bolt or pin connection allowable loads for the following conditions:

1. Withdrawal resistance; and
2. When there are more than 2 drift bolts or pins in a joint, allowable loads shall be further reduced by applying applicable modification factors shown in the AITC Table 6.3.

Nailed and Spiked Joints

Joints using nails or spikes shall conform to the provisions of AITC. For side grain withdrawal, the values in AITC Table 6.35 for wood having a specific gravity of 0.51 for Douglas Fir-Larch and a specific gravity of 0.42 for Hem-Fir shall be used. End grain withdrawal shall not be used. For lateral loading, the values in AITC Table 6.36 for wood species Group II for Douglas Fir-Larch and wood species Group III for Hem-Fir shall be used. Diameters listed in the tables apply to fasteners before application of any protective coating.

When more than 1 nail or spike is used in a joint, the total design value for the joint in withdrawal or lateral resistance shall be the sum of the design values for the individual nails or spikes.

The tabulated design values for lateral loads are valid only when the nail penetrates into the main member at least 11-diameters for Douglas Fir-Larch and 13-diameters for Hem-Fir. Note that the values are maximum values for the type and size of fastener shown. The tabulated values shall not be increased even if the actual penetration is exceeded.

When main member penetration is less than 11-diameters for Douglas Fir-Larch and 13-diameters for Hem-Fir, the design value shall be determined by straight-line interpolation between zero and the tabulated load, except that penetration shall not be less than ⅓ of that specified.

Double-headed or duplex nails used in falsework and formwork construction are shorter than common wire nails or box nails of the same size designation. They have less penetration into the main member and therefore their load-carrying capacity shall be adjusted accordingly.

Nail and spike minimum spacing in timber connections shall be as follows:

1. The average center-to-center distance between adjacent nails, measured in any direction, shall not be less than the required penetration into the main member for the size of nail being used; and
2. The minimum end distance in the side member, and the minimum edge distance in both the side member and the main member, shall not be less than ½ of the required penetration.

Allowable values for withdrawal and lateral load resistance are reduced when toe nails are used in accordance with the following:

1. For withdrawal loading, the design load shall not exceed ⅔ of the value shown in the applicable design table; and
2. For lateral loading, the design load shall not exceed ⅚ of the value shown in the applicable design table.

Toe nails are recommended to be driven at an approximate angle of 30-degrees with the piece and started approximately ⅓ of the length of the nail from the end or side of the piece.

Timber Connection Adjustment for Duration of Load

Tabulated values for timber fasteners are for normal duration of load and may be increased for short duration loading, except for connections used in falsework and formwork for post tensioned Structures and staged construction sequences. Duration of load adjustment for timber connections shall not be allowed for all post tensioned Structures and for staged construction sequences where delayed and/or staged loading occurs for any type of concrete Structure. The adjustment for duration of load as described in this section applies only to design values for timber connectors, such as nails, bolts, and lag screws. Allowable stresses for timber and structural steel components used in the connection, as described in Section 6-02.3(17)B, are maximums and thus shall not be increased.

Tabulated values for nails, bolts, and lag screws may be adjusted by the following duration-of-load factors:

1. 1.25 for falsework design governed by the minimum design horizontal load or greater (3-percent or greater of the dead load);
2. 1.33 for falsework design governed by wind load; and
3. 2.00 for falsework design governed by impact loading.

6-02.3(17)J Face Lumber, Studs, Wales, and Metal Forms

Elements of this section shall be designed for the loads, allowable stresses, deflections, and conditions which pertain from other subsections of Section 6-02.3(17).

Forms battered or inclined above the concrete will tend to lift up as concrete is placed and shall have positive anchorage or counterweights designed to resist uplift and shall be shown in the formwork plans. Where the concrete pouring sequence causes fresh concrete to be significantly higher along one side of tied forms than the opposite side, a positive form anchorage system shall be designed capable of resisting the imbalance of horizontal thrust, and prevent the dislocation and sliding of the entire form unit.

Wooden forms shall be faced with smooth sanded, exterior plywood. This plywood shall meet the requirements of the National Bureau of Standards, U.S. Product Standard PS 1, and the Design Specification of the American Plywood Association (APA). Each full sheet shall bear the APA stamp. The Contractor shall list in the form plans the grade and class of plywood. If the Engineer approves the manufacturer’s certification of structural properties, the Contractor may use plywood that does not carry the APA stamp. Plywood panels stamped “shop” or “shop cutting,” shall not be used.

Plyform is an APA plywood specifically designed and manufactured for concrete forming. Plyform differs from conventional exterior plywood grades in strength and the exterior face panels are sanded smooth and factory oiled. Likewise, there is a significant difference between grades designated Class 1, Class 2, and Structural I Plyform.

The grades of plywood for various form applications shall be as follows:

1. **Traffic and Pedestrian Barriers** (except those that will receive an architectural surface treatment) — Plywood used for these surfaces shall be APA grade High Density Overlaid (HDO) Plyform Class I. But if the Contractor coats the form to prevent it from leaving joint and grain marks on the surface, plywood that meets or exceeds APA grades B-B Plyform Class I or B-C (Group I species) may be used. Under this option, the Contractor shall provide for the Engineer’s approval a 4-foot square, test panel of concrete formed with the same plywood and coating as proposed in the form plans. This panel shall include 1 form joint along its centerline. The Contractor shall apply coating material, according to the manufacturer’s instructions, before applying chemical release agents.
2. **Other Exposed Surfaces** (all but those on traffic and pedestrian barriers) — Plywood used to form these surfaces shall meet or exceed the requirements of APA grades B-B Plyform Class I or B-C (Group I series). If 1 face is less than B quality, the B (or better) face shall contact the concrete.
3. **Unexposed Surfaces** (such as the undersides of roadway slabs between girders, the interiors of box girders, etc., and traffic and pedestrian barriers where surfaces will receive an architectural treatment) — Plywood used to form these surfaces may be APA grade CDX, provided the Contractor complies with stress and deflection requirements stated elsewhere in these Specifications.

Form joints on an exposed surface shall be in a horizontal or vertical plane. But in wingwalls and box girders, side form joints shall be placed at right angles and parallel to the Roadway grade. Joints parallel to studs or joists shall be backed by a stud or joist. Joints at right angles to studs and joists shall be backed by a stud or other backing the Engineer approves. Perpendicular backing is not required if studs or joists are spaced:

1. Nine-inches or less on center and covered with ½-inch plywood, or
2. Twelve-inches or less on center and covered with ¾-inch plywood.

The face grain of plywood shall run perpendicular to studs or joists unless shown otherwise on the Contractor's formwork plans and approved by the Engineer. Proposals to deviate from the perpendicular orientation shall be accompanied by supporting calculations of the stresses and deflections.

Forming for all exposed curved surfaces shall follow the shape of the curve shown in the Contract Plans and shall not be chorded except as follows. On any retaining wall that follows a horizontal circular curve, the wall stems may be a series of short chords if:

1. The chords within the panel are the same length, unless otherwise approved by the Engineer;
2. The chords do not vary from a true curve by more than ½-inch at any point; and
3. All panel points are on the true curve.

Where architectural treatment is required, the angle point for chords in wall stems shall fall at vertical rustication joints.

For exposed surfaces of abutments, wingwalls, piers, retaining walls, and columns, the Contractor shall build forms of plywood at least ¾-inch thick with studs no more than 12-inches on center. The Engineer may approve exceptions, but deflection of the plywood, studs, or wales shall never exceed $^1/_{360}$ of the span (or $^1/_{270}$ of the span for unexposed surfaces, including the bottom of the deck slab between girders).

All form plywood shall be at least ½-inch thick except on sharply curved surfaces. There, the Contractor may use ¼-inch plywood if it is backed firmly with heavier material.

Round columns or rounded pier shafts shall be formed with a self-supporting metal shell form or form tube that leaves a smooth, nonspiralling surface. Wood forms are not permitted.

Metal forms shall not be used elsewhere unless the Engineer is satisfied with the surface and approves in writing. The Engineer may withdraw approval for metal forms at any time. If permitted to use a combination of wood and metal in forms, the Contractor shall coat the forms so that the texture produced by the wood matches that of the metal. Aluminum shall not be used for metal forms.

For design purposes, the Contractor shall assume that on vertical surfaces concrete exerts 150-pounds per sq. ft. per foot of depth. However, when the depth is reached where the rate of placement controls the pressure, the following table applies:

Rate of Placing Feet per Hour	Pressure, Pounds per Square Foot for Temperature of Concrete as Shown	
	60°F	70°F and above
2	470	375
3	640	565
4	725	625
5	815	690
6	900	750
7	990	815
8	1,075	875
9	1,165	935
10	1,250	1,000
15	1,670	1,300

The pressures in the above table have been increased to provide an allowance for the vibration and impact.

All corners shall be beveled ¾-inch. However, footings, footing pedestals, and seals need not be beveled unless required in the Plans.

All forms shall be as mortar-tight as possible with no water standing in them as the concrete is placed.

The Contractor shall apply a parting compound on forms for exposed concrete surfaces. This compound shall be a chemical release agent that permits the forms to separate cleanly from the concrete. The compound shall not penetrate or stain the surface and shall not attract dirt or other foreign matter. After the forms are removed, the concrete surface shall be dust-free and have a uniform appearance. The Contractor shall apply the compound at the manufacturer's recommended rate to produce a surface free of dusting action and yet provide easy removal of the forms.

If an exposed concrete surface will be sealed, the release agent shall not contain silicone resin. Before applying the agent, the Contractor shall provide the Engineer a written statement from the manufacturer stating whether the resin in the base material is silicone or nonsilicone.

The Contractor shall select a parting compound from the current Qualified Products List, or submit to the Engineer a sample of the parting compound at least 10-working days before its use. Approval or disapproval shall be based on Laboratory test results or selection off the current Qualified Products List.

The Engineer may reject any forms that will not produce a satisfactory surface.

6-02.3(17)K Concrete Forms on Steel Spans

Concrete forms on all steel Structures shall be removable and shall not remain in place. Where needed, the forms shall have openings for truss or girder members. Each opening shall be large enough to leave at least 1½-inches between the concrete and steel on all sides of the steel member after the forms have been removed. Unit Contract prices cover all costs related to these openings.

Any form support for a roadway slab that rests on a plate girder flange shall apply the load within 6-inches of the girder web centerline. The Contractor shall not weld any part of the form to any steel member.

The compression member or bottom connection of cantilever formwork support brackets shall bear either within 6-inches maximum vertically of the bottom flange or within 6-inches maximum horizontally of a vertical web stiffener. The Contractor shall also furnish and install temporary struts and ties to prevent rotation of the steel girder. Partial depth cantilever formwork support brackets that do not conform to the above requirements shall not be used, unless the Contractor submits details showing the additional formwork struts and ties used to brace the steel girder against web distortion caused by the partial depth bracket, and receives the Engineer's approval of the submittal.

If the Engineer permits bolt holes in the web to support form brackets, the holes shall be shop drilled unless otherwise approved by the Engineer. The Contractor shall fill the holes with fully torqued AASHTO M 164 bolts per Section 6-03.3(33). Each bolt head shall be placed on the exterior side of the web. There shall be no holes made in the flanges.

6-02.3(17)L Finishing Machine Support System

Before using any finishing machine, the Contractor shall obtain the Engineer's approval of detailed drawings that show the system proposed to support it. The Contractor shall not attach this (or any other) equipment support system to the sides or suspend it from any girder unless the Engineer permits. The Engineer will not permit such a method if it will unduly alter stress patterns or create too much stress in the girder.

6-02.3(17)M Restricted Overhead Clearance Sign

The Contractor shall notify the Engineer not less than 15-working days before the anticipated start of each falsework and girder erection operation whenever such falsework or girders will reduce clearances available to the public traffic. Falsework openings shall not be more restrictive to traffic than shown in the Contract Plans.

Where the height of vehicular openings through falsework is less than 15-feet, a W 12-2 "Low Clearance Symbol Sign" shall be erected on the Shoulder in advance of the falsework and 2 or more W 12-301 and/or W 12-302 signs shall be attached to the falsework to provide accurate usable clearance information over the entire falsework opening. The posted low clearance shall include an allowance for anticipated falsework girder deflection (rounded-up to the next whole inch) due to design dead load, including all successive concrete pours. W 12-302 signs shall be used to designate prominent clearance restrictions and limits of usable clearance. In addition, where the clearance is less than the legal height limit (14-feet 0-inches), a W 12-2 sign shall be erected in advance of the nearest intersecting road or wide point in the road at which a vehicle can detour or turn around. A W 13-501 sign indicating the distance to the low clearance shall be installed below the advance sign. The Engineer will furnish the above noted signs and the Contractor shall erect and maintain them, all in accordance with Section 1-10.3(3).

When erecting falsework that restricts overhead clearance above a railroad track, the Contractor shall immediately (as soon as the restriction occurs) place restricted overhead clearance signs. Sign details are shown in the Standard Plans. Unit Contract prices cover all costs relating to these signs.

6-02.3(17)N Removal of Falsework and Forms

The Engineer will decide, on the basis of post-placement curing conditions, the exact number of days that shall elapse before form or falsework removal. If the Engineer does not specify otherwise, the Contractor may request to remove forms based on the criteria listed in the table below. Both compressive strength and number of days criteria must be met if both are listed. The number of days shall be from the time of the last pour the forms support. In no case shall the Contractor remove forms or falsework without the Engineer's approval.

Concrete Placed In	Percent of Specified Minimum Compressive Strength	Number of Days
Columns, walls, non-sloping box girder webs, abutments, footings, traffic and pedestrian barriers, and any other side form not supporting the concrete weight.	—	3
Crossbeams, pier caps, struts, inclined columns and inclined walls.[1]	80	5
Roadway slabs supported on wood or steel stringers or on steel or prestressed concrete girders.[1, 2]	80	10
Box girders, T-beam girders, and flat-slab Superstructure.[1, 2]	80	14
Arches.[1, 2]	—	21

[1] Where forms support the concrete weight.

[2] Where continuous spans are involved, the time for all spans will be determined by the last concrete placed affecting any span.

Before releasing supports from beneath beams and girders, the Contractor shall remove forms from columns to enable the Engineer to inspect the column concrete.

The Contractor may remove the side forms of footings 24-hours after concrete placement if a curing compound is applied immediately. This compound shall not be applied to that area of the construction joint between the footing and the column or wall.

The Contractor may remove side forms not supporting the concrete weight 24-hours after concrete placement if the concrete reaches a compressive strength of 1400-psi before form removal. This strength shall be proved by test cylinders made from the last concrete placed into the form. The cylinders shall be cured according to WSDOT FOP for AASHTO T 23.

The Contractor may remove side forms, traffic barrier forms, and pedestrian barrier forms after 24-hours if these forms are made of steel or dense plywood, an approved water reducing additive is used, and the concrete reaches a compressive strength of 1400-psi before form removal. This strength shall be proved by test cylinders made from the last concrete placed into the form. The cylinders shall be cured according to WSDOT FOP for AASHTO T 23.

Wet curing shall comply with the requirements of Section 6-02.3(11). The concrete surface shall not become dry during form removal or during the entire curing period.

Before placing forms for traffic and pedestrian barriers, the Contractor shall completely release all falsework under spans.

Before releasing forms under concrete subjected to temperatures colder than 50°F, the Contractor shall first prove that the concrete meets desired strength — regardless of the time that has elapsed.

The Engineer may approve leaving in place forms for footings in cofferdams or cribs. This decision will be based on whether removing them would harm the cofferdam or crib and whether the forms will show in the finished Structure.

All cells of a box girder Structure which have permanent access shall have all forms completely removed, including the roadway deck forms. All debris and all projections into the cells shall be removed. Unless otherwise shown in the Plans, the roadway slab interior forms in all other cells where no permanent access is available, may be left in place.

Falsework and forms supporting sloping exterior webs shall not be released until the roadway deck and deck overhang concrete has obtained its removal strength and number of days criteria listed in the table above. Stem reshoring shall not be used.

Open joints shown in the Plans shall have all forms completely removed, including Styrofoam products and form anchors, allowing the completed Structure to move freely.

If the Contractor intends to support or suspend falsework and formwork from the bridge Structure while the falsework and formwork is being removed, the Contractor shall submit a falsework and formwork removal plan and calculations for review and approval. The falsework and formwork removal plan shall include the following:

1. The location and size of any cast-in-place falsework lowering holes and how the holes are to be filled;
2. The location, capacity, and size of any attachments, beams, cables, and other hardware used to attach to the Structure or support the falsework and formwork;
3. The type, capacity and factor of safety, weight, and spacing of points of reaction of lowering equipment; and
4. The weight at each support point of the falsework and formwork being lowered.

All other forms shall be removed whether above or below the level of the ground or water. Sections 6-02.3(7) and 6-02.3(8) govern form removal for concrete exposed to sea water or to alkaline water or soil. The forms inside of hollow piers, girders, abutments, etc. shall be removed through openings shown in the Plans or approved by the Engineer.

6-02.3(17)O Early Concrete Test Cylinder Breaks

The fabrication, curing, and testing of the early cylinders shall be the responsibility of the Contractor. Early cylinders are defined as all cylinders tested in advance of the design age of 28-days whose purpose is to determine the in-place strength of concrete in a Structure prior to applying loads or stresses. The Contractor shall retain a testing Laboratory to perform this Work. Testing Laboratories' equipment shall be calibrated within 1-year prior to testing and testers shall be either ACI certified or qualified in accordance with AASHTO R 18.

The concrete cylinders shall be molded in accordance with WSDOT FOP for AASHTO T 23 from concrete last placed in the forms and representative of the quality of concrete placed in that pour.

The cylinders shall be cured in accordance with WSDOT FOP for AASHTO T 23. The Engineer may approve the use of cure boxes meeting the requirements of this test method. Special cure boxes to enhance cylinder strength will not be allowed.

The concrete cylinders shall be tested for compressive strength in accordance with AASHTO T 22. The number of early cylinder breaks shall be in accordance with the Contractor's need and as approved by the Engineer.

The Contractor shall furnish the Engineer with all test results, proof of equipment calibration, and tester's certification. The test results will be reviewed and approved before any forms are removed. The Contractor shall not remove forms without the approval of the Engineer.

All costs in connection with furnishing cylinder molds, fabrication, curing, and testing of early cylinders shall be included in the unit Contract prices for the various Bid items of Work involved.

6-02.3(18) Placing Anchor Bolts

The Contractor shall comply with the following requirements in setting anchor bolts in piers, abutments, or pedestals:

1. If set in the wet concrete, the bolts shall be accurately placed before the concrete is placed.
2. If the bolts are set in drilled holes, hole diameter shall exceed bolt diameter by at least 1-inch. Grouting shall comply with Section 6-02.3(20).
3. If the bolts are set in pipe, grouting shall comply with Section 6-02.3(20).
4. If freezing weather occurs before bolts can be grouted into sleeves or holes, they shall be filled with an approved antifreeze solution (non-evaporating).

6-02.3(19) Bridge Bearings

6-02.3(19)A Vacant

6-02.3(19)B Bridge Bearing Assemblies

For all fixed, sliding, or rolling bearings, the Contractor shall:

1. Machine all sliding and rolling surfaces true, smooth, and parallel to the movement of the bearing;
2. Polish all sliding surfaces;
3. Anchor expansion bearings securely, setting them true to line and grade;
4. Avoid placing concrete in such a way that it might interfere with the free action of any sliding or rolling surface.

Grout placement under steel bearings shall comply with Section 6-02.3(20).

6-02.3(20) Grout for Anchor Bolts and Bridge Bearings

Grout shall be a prepackaged grout, mixed, placed, cured as recommended by the manufacturer, or the grout shall be produced using Type I or II Portland cement, fine aggregate Class 1 or Class 2, and water, in accordance with these Specifications.

Grout shall meet the following requirements:

Requirement	Compressive Strength
Test Method	AASHTO Test Method T 106
Values	4,000-psi @ 7-days

Grout shall be a workable mix with flowability suitable for the intended application.

If the Contractor elects to use a prepackaged grout, a material sample and Laboratory test data from an independent testing Laboratory shall be submitted to the Engineer for approval with the request for approval of material sources.

If the Contractor elects to use a grout consisting of Type I or II Portland cement, fine aggregate Class 1, admixture, and water, the mix proportions and Laboratory test data from an independent test Laboratory shall be submitted to the Engineer for approval with the request for approval of material sources.

The Contractor shall receive approval from the Engineer before using the grout.

Field grout cubes shall be made in accordance with WSDOT Test Method 813 for either prepackaged grout or a Contractor provided mix when requested by the Engineer, but not less than 1 per bridge pier or 1 per day.

Before placing grout, the concrete on which it is to be placed shall be thoroughly cleaned, roughened, and wetted with water to ensure proper bonding. The grout pad shall be cured as recommended by the manufacturer or kept continuously wet with water for 3-days. The grout pad may be loaded when a minimum of 4000-psi compressive strength is attained.

Before placing grout into anchor bolt sleeves or holes, the cavity shall be thoroughly cleaned and wetted to ensure proper bonding.

To grout bridge bearing masonry plates, the Contractor shall:

1. Build a form approximately 4-inches high with sides 4-inches outside the base of each masonry plate;
2. Fill each form to the top with grout;
3. Work grout under all parts of each masonry plate;
4. Remove each form after the grout has hardened;
5. Remove the grout outside each masonry plate to the base of the masonry plate;
6. Bevel off the grout neatly to the top of the masonry; and
7. Place no additional load on the masonry plate until the grout has set at least 72-hours.

After all grout under the masonry plate and in the anchor bolt cavities has attained a minimum strength of 4,000-psi, the anchor bolt nuts shall be tightened to snug-tight. "Snug-tight" means either the tightness reached by (1) a few blows from an impact wrench, or (2) the full effort of a person using a spud wrench. Once the nut is snug-tight, the anchor bolt threads shall be burred just enough to prevent loosening of the nut.

6-02.3(21) Drainage of Box Girder Cells

To drain box girder cells, the Contractor shall provide and install, according to details in the Plans, short lengths of nonmetallic pipe in the bottom slab at the low point of each cell. The pipe shall have a minimum inside diameter of 4-inches. If the difference in Plan elevation is 2-inches or less, the Contractor shall install pipe in each end of the box girder cell. All drainage holes shall be screened in accordance with the Plan details.

6-02.3(22) Drainage of Substructure

The Contractor shall use weep holes and gravel backfill that complies with Section 9-03.12(2) to drain fill material behind retaining walls, abutments, tunnels, and wingwalls. To maintain thorough drainage, weep holes shall be placed as low as possible. Weep holes shall be covered with geotextile meeting the requirements of Section 9-33.2, Table 2 Class C before backfilling. Geotextile screening shall be bonded to the concrete with an approved adhesive. Gravel backfill shall be placed and compacted as required in Section 2-09.3(1)E. In addition, if the Plans require, tiling, French or rock drains, or other drainage devices shall be installed.

If underdrains are not installed behind the wall or abutment, all backfill within 18-inches of weep holes shall comply with Section 9-03.12(4). Unless the Plans require otherwise, all other backfill behind the wall or abutment shall be gravel backfill for walls.

6-02.3(23) Opening to Traffic

Bridges with a roadway slab made of Portland cement concrete shall remain closed to all traffic, including construction equipment, until the concrete has reached the 28-day specified compressive strength. This strength shall be determined with cylinders made of the same concrete as the Roadway and cured under the same conditions. A concrete deck bridge shall never be opened to traffic earlier than 10-days after the deck concrete was placed and never before the Engineer has approved.

For load restrictions on bridges under construction, refer to Section 6-01.6.

6-02.3(24) Reinforcement

Although the Plans normally include a bar list and bending diagram, these shall be used at the Contractor's risk. The Engineer advises the Contractor to check the order from the Plans.

Before delivery of the reinforcing bars, the Contractor shall submit to the Engineer 2 informational copies of the supplemental bending diagrams.

Various steel reinforcing bars, including those in crossbeams, may be shown as straight in the bar list sheets of the Plans. The Contractor shall bend these bars as required to conform to the configuration of the Structure and as detailed in the Plans.

6-02.3(24)A Field Bending

If the Plans call for field bending of steel reinforcing bars, the Contractor shall bend them in keeping with the Structure configuration and the Plans and Specifications.

Bending steel reinforcing bars partly embedded in concrete shall be done as follows:

Field bending shall not be done:

1. On bars size No. 14 or No. 18,
2. When air temperature is lower than 45°F,
3. By means of hammer blows or pipe sleeves, or
4. While bar temperature is in the range of 400° to 700°F.

In field-bending steel reinforcing bars, the Contractor shall:

1. Make the bend gradually;
2. Apply heat as described in Tables 2 and 3 for bending bar sizes No. 6 thru No. 11 and for bending bar sizes No. 5 and smaller when the bars have been previously bent. Previously unbent bars of sizes No. 5 and smaller may be bent without heating;
3. Use a bending tool equipped with a bending diameter as listed in Table 1;
4. Limit any bend to these maximums — 135-degrees for bars smaller than size No. 9, and 90-degrees for bars size No. 9 and No. 11;
5. Straighten by moving a hickey bar (if used) progressively around the bend.

In applying heat for field-bending steel reinforcing bars, the Contractor shall:

1. Use a method that will avoid damages to the concrete;
2. Insulate any concrete within 6-inches of the heated bar area;
3. Ensure, by using temperature-indicating crayons or other suitable means, that steel temperature never exceeds the maximum temperatures shown in Table 2 below;

4. Maintain the steel temperature within the required range shown in Table 2 below during the entire bending process;
5. Apply 2 heat tips simultaneously at opposite sides of bars larger than size No. 6 to assure a uniform temperature throughout the thickness of the bar. For size No. 6 and smaller bars, apply 2 heat tips, if necessary;
6. Apply the heat for a long enough time that within the bend area the entire thickness of the bar — including its center — reaches the required temperature;
7. Bend immediately after the required temperature has been reached;
8. Heat at least as much of the bar as Table 3 below requires;
9. Locate the heated section of the bar to include the entire bending length; and
10. Never cool bars artificially with water, forced air, or other means.

Table 1
Bending Diameters for Field-Bending Reinforcing Bars

	Bend Diameter/Bar Diameter Ratio	
Bar Size	**Heat Not Applied**	**Heat Applied**
No. 4, No. 5	8	8
No. 6 through No. 9	Not Permitted	8
No. 10, No. 11	Not Permitted	10

The minimum bending diameters for stirrups and ties for No. 4 and No. 5 bars when heat is not applied shall be specified in Section 9-07.

Table 2
Preheating Temperatures for Field-Bending Reinforcing Bars

	Temperature (F)	
Bar Size	**Minimum**	**Maximum**
No. 4	1,200	1,250
No. 5, No. 6	1,350	1,400
No. 7 through No. 9	1,400	1,450
No. 10, No. 11	1,450	1,500

Table 3
Minimum Bar Length to be Heated (d = nominal diameter of bar)

	Bend Angle		
Bar Size	**45°**	**90°**	**135°**
No. 4 through No. 8	8d	12d	15d
No. 9	8d	12d	Not Permitted
No. 10, No. 11	9d	14d	Not Permitted

6-02.3(24)B Protection of Materials

The Contractor shall protect reinforcing steel from all damage. When placed into the Structure, the steel shall be free from dirt, loose rust or mill scale, paint, oil, and other foreign matter.

When transporting, storing, or constructing in close proximity to bodies of salt water, plain and epoxy-coated steel reinforcing bar shall be kept in enclosures that provide protection from the elements.

If plain or epoxy-coated steel reinforcing bar is exposed to mist, spray, or fog that may contain salt, it shall be flushed with fresh water prior to concrete placement.

When the Engineer requires protection for reinforcing steel that will remain exposed for a length of time, the Contractor shall protect the reinforcing steel:

1. By cleaning and applying a coat of paint Formula No. A-9-73 over all exposed surfaces of steel, or
2. By cleaning and painting paint Formula No. A-9-73 on the first 6-inches of the steel bars protruding from the concrete and covering the bars with polyethylene sleeves.

The paint shall have a minimum dry film thickness of 1-mil.

6-02.3(24)C Placing and Fastening

The Contractor shall position reinforcing steel as the Plans require and shall ensure that the steel does not move as the concrete is placed.

When spacing between bars is 1-foot or more, they shall be tied at all intersections. When spacing is less than 1-foot, every other intersection shall be tied. If the Plans require bundled bars, they shall be tied together with wires at least every 6-feet. All epoxy-coated bars in the top mat of the roadway slab shall be tied at all intersections. Other epoxy-coated bars shall also be tied at all intersections, but shall be tied at alternate intersections when spacing is less than 1-foot in each direction. Wire used for tying epoxy-coated reinforcing steel shall be plastic coated. **Tack welding is not permitted on reinforcing steel**.

Abrupt bends in the steel are permitted only when one steel member bends around another. Vertical stirrups shall pass around main reinforcement or be firmly attached to it.

For slip-formed concrete, the reinforcing steel bars shall be tied at all intersections and cross braced to keep the cage from moving during concrete placement. Cross bracing shall be with additional reinforcing steel. Cross bracing shall be placed both longitudinally and transversely.

After reinforcing steel bars are placed in a traffic or pedestrian barrier and prior to slip-form concrete placement, the Contractor shall check clearances and reinforcing steel bar placement. This check shall be accomplished by using a template or by operating the slip-form machine over the entire length of the traffic or pedestrian barrier. All clearance and reinforcing steel bar placement deficiencies shall be corrected by the Contractor before slip-form concrete placement.

Mortar blocks (or other approved devices) shall be used to maintain the concrete coverage required by the Plans. The Mortar blocks shall:

1. Have a bearing surface measuring not greater than 2-inches in either dimension, and
2. Have a compressive strength equal to that of the concrete in which they are embedded.

In slabs, each mortar cube shall have either: (1) a grooved top that will hold the reinforcing bar in place, or (2) an embedded wire that protrudes and is tied to the reinforcing steel. If this wire is used around epoxy-coated bars, it shall be coated with plastic.

Mortar blocks may be accepted on a Manufacturers Certificate of Compliance, which shall include test results on sets of two 2-inch square specimens per AASHTO T 106. Each pair of specimens shall represent 2,500 or fewer mortar blocks and shall be made of the same mortar as the blocks and cured under the same conditions.

In lieu of mortar blocks, the Contractor may use metal or plastic chair supports to hold uncoated bars. Any surface of a metal chair support that will not be covered by at least ½-inch of concrete shall be 1 of the following:

1. Hot-dip galvanized after fabrication in keeping with AASHTO M 232 Class D,
2. Coated with plastic firmly bonded to the metal. This plastic shall be at least $^{3}/_{32}$-inch thick where it touches the form and shall not react chemically with the concrete when tested in the State Materials Laboratory. The plastic shall not shatter or crack at or above -5°F and shall not deform enough to expose the metal at or below 200°F, or
3. Stainless steel that meet the requirements of ASTM A 493, Type 302. Stainless steel chair supports are not required to be galvanized or plastic coated.

In lieu of mortar blocks, epoxy-coated reinforcing bars may be supported by 1 of the following:

1. Metal chair supports coated entirely with a dielectric material such as epoxy or plastic,
2. Other epoxy-coated reinforcing bars, or
3. Plastic chair supports.

Plastic chair supports shall be lightweight, non-porous, and chemically inert in concrete. Plastic chair supports shall have rounded seatings, shall not deform under load during normal temperatures, and shall not shatter or crack under impact loading in cold weather. Plastic chair supports shall be placed at spacings greater than 1-foot along the bar and shall have at least 25-percent of their gross place area perforated to compensate for the difference in the coefficient of thermal expansion between plastic and concrete. The shape and configuration of plastic supports shall permit complete concrete consolidation in and around the support.

In roadway and sidewalk slabs, the Contractor shall place reinforcing steel mats carefully to provide the required concrete cover. A “mat” is 2 layers of steel. Top and bottom mats shall be supported enough to hold both in their proper positions. If No. 4 bars make up the lower layer of steel in a mat, it shall be blocked at not more than 3-foot intervals (or 4-foot intervals for bars No. 5 and larger). Wire ties to girder stirrups shall not be considered as blocking. To provide a rigid mat, the Contractor shall add other supports and tie wires to the top mat as needed.

If a bar will interfere with a bridge drain, it shall be bent in the field to bypass the drain.

Clearances shall be at least:

4-inches between:	Main bars and the top of any concrete masonry exposed to the action of salt or alkaline water.
3-inches between:	Main bars and the top of any concrete deposited against earth without intervening forms.
2½-inches between:	Adjacent bars in a layer. Roadway slab bars and the top of the roadway slab.

2-inches between:	Adjacent layers. Main bars and the surface of concrete exposed to earth or weather (except in roadway slabs). Reinforcing bars and the faces of forms for exposed aggregate finish.
1½-inches between:	Main bars and the surface of concrete not exposed to earth or weather. Slab bars and the top of the slab (except roadway slabs). Barrier and curb bars and the surface of the concrete. Stirrups and ties and the surface of the concrete exposed to earth or weather.
1-inch between:	Slab bars and the bottom of the slab. Stirrups and ties and the surface of the concrete not exposed to earth or weather.

Reinforcing steel bars shall not vary more than the following tolerances from their position shown in the Plans:

Members 10-inches or less in thickness	±¼-in.
Members more than 10-inches in thickness	±⅜-in.
Drilled Shafts top of rebar cage elevation	+6-in./-3-in.
Except:	
The distance between the nearest reinforcingsteel bar surface and the top surface of the roadway deck slab	+¼-in.
Longitudinal spacing of bends and ends of bars	±1-in.
Length of bar laps	-1½-in.
Embedded length	
No 3 through No. 11	-1-in.
No. 14 through No. 18	-2-in.
When reinforcing steel bars are to be placedat equal spacing within a plane:	
Stirrups and ties	±1-in.
All other reinforcement	±1 bar dia.

Before placing any concrete, the Contractor shall:

1. Clean all mortar from reinforcement, and
2. Obtain the Engineer's permission to place concrete after the Engineer has inspected the placement of the reinforcing steel. (Any concrete placed without the Engineer's permission shall be rejected and removed.)

6-02.3(24)D Splicing

The Contractor shall supply steel reinforcing bars in the full lengths the Plans require. Unless the Engineer approves in writing, the Contractor shall not change the number, type, or location of splices.

The Engineer may permit the Contractor to use thermal or mechanical splices in place of the method shown in the Plans if they are of an approved design. Use of a new design may be granted if:

1. The Contractor provides technical data and proof from the manufacturer that the design will perform satisfactorily, and
2. Sample splices and materials from the manufacturer pass the Engineer's tests.

After a design has been approved, any changes in detail or material shall require new approval.

The Contractor shall:

1. Not lap-splice reinforcing bars Nos. 14 or 18.
2. Not permit any welded or mechanical splice to deviate in alignment more than ¼-inch per 3½-feet of bar.
3. Distribute splices evenly, grouping them together only at points of low tensile stress.
4. Ensure at least 2-inches clearance between any splice and the nearest bar or the surface of the concrete (or 1½-inch for the length of the sleeve on mechanical splices).
5. Rigidly clamp or wire all splices in a way the Engineer approves.
6. Place lap-spliced bars in contact for the length of the splice and tie them together near each end.
7. Securely fasten the ends and edges of welded-wire-fabric reinforcement, overlapping them enough to maintain even strength.

6-02.3(24)E Welding Reinforcing Steel

Welding of steel reinforcing bars shall conform to the requirements of ANSI/AWS D1.4 Structural Welding Code - Reinforcing Steel, latest edition, except where superseded by the Special Provisions, Plans, and these Specifications.

Before any welding begins, the Contractor shall obtain the Engineer's approval of a written welding procedure for each type of welded splice to be used, including the weld procedure Specifications and joint details. The weld procedure Specifications shall be written on a form taken from AWS D1.4 Annex A, or equivalent. Test results of tensile strength, macroetch, and visual examination shall be included. The form shall be signed and dated.

Welders shall be qualified in accordance with AWS D1.4. The Contractor shall be responsible for the testing and qualification of welders, and shall submit welder qualification and retention records to the Engineer for approval. The weld joint and welding position a welder is qualified in shall be in accordance with AWS D1.4. The welder qualifications shall remain in effect indefinitely unless, (1) the welder is not engaged in a given process of welding for which the welder is qualified for a period exceeding 6-months, or (2) there is some specific reason to question a welder's ability.

Filler metals used for welding reinforcing bars shall be in accordance with AWS D1.4 Table 5.1. All filler metals shall be low-hydrogen and handled in compliance with low-hydrogen practices specified in the AWS code.

All welding shall be protected from air currents, drafts, and precipitation to prevent loss of heat or loss of arc shielding. Short circuiting transfer with gas metal arc welding will not be allowed. Slugging of welds will not be allowed.

The minimum preheat and interpass temperature for welding shall be in accordance with AWS D1.4 Table 5.2 and mill certification of carbon equivalence, per lot of reinforcing. Preheating shall be applied to the reinforcing bars and other splice members within 6-inches of the weld, unless limited by the available lengths of the bars or splice member.

Generally, post heating of welded splices is only required for direct butt welded splices of AASHTO M 31/ASTM A 615 Grade 60 bars size No. 9 or larger and shall be done immediately after welding before the splice has cooled to 700°F. Post heating shall not be less than 800°F nor more than 1,000°F and held at this temperature for not less than 10-minutes before allowing the splice to cool naturally to ambient temperature.

For the purpose of compatibility with AWS D1.4, welded lap splices for spiral or hoop reinforcing shall be considered Flare-V groove welds, indirect butt joints.

The Contractor is responsible for using a welding sequence that will limit the alignment distortion of the bars due to the effects of welding. The maximum out-of-line permitted will be ¼-inch from a 3.5-foot straight-edge centered on the weld and in line with the bar.

The following procedure for welding steel reinforcing bars is recommended:

Sheared bar ends shall be burned or sawed off a minimum of ½-inch to completely remove the ruptured portion of the steel shear area prior to welding butt splices. Surfaces to be welded shall be smooth, uniform, and free from fins, tears, cracks, and other defects. Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, moisture, grease, paint, epoxy covering, or other foreign materials. All tack welds shall be within the area of the final weld. No other tack weld will be permitted. Double bevel groove welds require chipping, grinding, or gouging to sound metal at the root of the weld before welding the other side. Progression of vertical welding shall be upward. The ground wire from the welding machine shall be clamped to the bar being welded.

Should the Contractor elect to use a procedure which differs in any way from the procedure recommended, the Contractor shall submit the changes, in writing, to the Engineer for approval. Approved weld procedures shall be strictly followed.

6-02.3(24)F Mechanical Splices

The Contractor shall form mechanical splices with an Engineer-approved system using sleeve filler metal, threaded coupling, or another method that complies with this section.

If necessary to maintain required clearances after the splices are in place, the Contractor shall adjust, relocate, or add stirrups, ties, and bars.

Before splicing, the Contractor shall provide the Engineer with the following information for each shipment of splice material:

1. The type or series identification (and heat treatment lot number for threaded-sleeve splices),
2. The grade and size of bars to be spliced,
3. A manufacturer’s catalog with complete data on material and procedures,
4. A written statement from the manufacturer that the material is identical to that used earlier by the Engineer in testing and approving the system design, and
5. A written statement from the Contractor that the system and materials will be used according to the manufacturer’s instructions and all requirements of this section.

All splices shall meet these criteria:

1. Tension splices shall develop at least 130-percent of the yield tensile strength specified for the unspliced bar. The ultimate tensile strength of the sleeve shall exceed that of the other parts of the completed splice.
2. AASHTO M 31 bars within a splice sleeve shall not slip more than 0.03-inch for Grade 40 bars, nor more than 0.045-inch for Grade 60 bars. This slippage shall be measured between gage points clear of the splice sleeve. Measurements shall be taken at an initial load of 3,000-psi and again after loading to 90-percent of the minimum specified yield strength for the unspliced bar and then relaxed to 3,000-psi.
3. Maximum allowable bar size:
   a. Mechanical butt splice No. 14
   b. Mechanical lap splice No. 6

The Engineer will visually inspect the splices and accept all that appear to conform with the test samples. For sleeve-filler splices, the Engineer will allow voids within the limits on file in the design approval. If the Engineer considers any splice defective, it shall be removed and replaced at the Contractor's expense.

In preparing sleeve-filler metal splices, the Contractor shall:

1. Clean the bar surfaces by: (a) oxyacetylene torch followed by power wire brushing, or (b) abrasive blasting;
2. Remove all slag, mill scale, rust, and other foreign matter from all surfaces within and 2-inches beyond the sleeve;
3. Grind down any projection on the bar that would prevent placing the sleeve;
4. Prepare the ends of the bars as the splice manufacturer recommends and as the approved procedure requires; and
5. Preheat, just before adding the filler, the entire sleeve and bar ends to 300°F, plus or minus 50°F. (If a gas torch is used, the flame shall not be directed into the sleeve.)

When a metallic, sleeve-filler splice is used (or any other system requiring special equipment), both the system and the operator shall qualify in the following way under the supervision of the State Materials and Fabrication Inspector. The operator shall prepare 6 test splices (3 vertical, 3 horizontal) using bars having the same AASHTO Designation and size (maximum) as those to be used in the Work. Each test sample shall be 42-inches long, made up of two 21-inch bars joined end-to-end by the splice. The bar alignment shall not deviate more than ⅛-inch from a straight line over the whole length of the sample. All 6 samples must meet the tensile strength and slip criteria specified in this section.

The Contractor shall provide labor, materials, and equipment for making these test samples at no expense to the Contracting Agency. The Contracting Agency will test the samples at no cost to the Contractor.

6-02.3(24)G Job Control Tests

As the Work progresses, the Engineer may require the Contractor to provide a sample splice (thermal or mechanical) to be used in a job control test. The operator shall create this sample on the job site with the Engineer present using bars of the same size as those being spliced in the Work. The sample shall comply with all requirements of these Specifications, and is in addition to all other sample splices required for qualification. The

Engineer will require no more than 2 samples on any project with fewer than 200-splices and no more than 1 sample per 100-splices on any project with more than 200-splices.

6-02.3(24)H Epoxy-Coated Steel Reinforcing Bar

This Work is furnishing, fabricating, coating, and placing epoxy-coated steel reinforcing bars as the Plans, these Specifications, and the Special Provisions require. Coating material shall be applied electrostatically, by spraying, or by the fluidized-bed method.

All epoxy-coated bars shall comply with the requirements of Section 9-07. Fabrication may occur before or after coating.

The Contractor shall protect epoxy-coated bars from damage using padded or nonmetallic slings and straps free from dirt or grit. To prevent abrasion from bending or sagging, the Contractor shall lift bundled bars with a strong-back, multiple supports, or a platform bridge. Bundled bars shall not be dropped or dragged. During shop or field storage, bars shall rest on wooden or padded cribbing. The Contractor may substitute other methods for protecting the bars if the Engineer approves. If the Engineer believes the coated bars have been badly damaged, they will be rejected.

Metal chairs and supports shall be coated with epoxy (or another inert coating if the Engineer approves). The Contractor may use other support devices with the Engineer's approval. Plastic coated tie wires (approved by the Engineer) shall be used to protect the coated bars from being damaged during placement.

The bars shall be placed as the Plans require and held firmly in place during placing and setting of the concrete. All bars shall be placed and fastened as specified in Section 6-02.3(24)C.

In the interval between installing coated bars and concreting the deck, the Contractor shall protect the coating from damage that might result from other construction Work.

The Engineer will inspect the coated bars after they are placed and before the deck concrete is placed. The Contractor shall patch any areas that show significant damage (as defined below).

Significant damage means any opening in the coating that exposes the steel in an area that exceeds:

1. 0.05-square inch (approximately ¼-inch square or ¼ -inch in diameter or the equivalent).
2. 0.012-square inches (approximately ⅛-inch square or ⅛-inch in diameter) when the opening is within ¼-inch of another opening of equal or larger size.
3. 6-inches long, any width.
4. 0.50-square inch aggregate area in any 1-foot length of bar.

The Contractor shall patch significantly damaged areas with Engineer-approved patching material obtained from the epoxy resin manufacturer. This material shall be compatible with the coating and inert in concrete. Areas to be patched shall be clean and free of surface contaminants. Patching shall be done before oxidation occurs and according to the resin manufacturer's instructions.

6-02.3(25) Prestressed Concrete Girders

The Contractor shall perform quality control inspection. The manufacturing plant of prestressed concrete girders shall be certified by the Precast/Prestressed Concrete Institute's Plant Certification Program for the type of prestressed member to be produced and shall be approved by WSDOT as a Certified Prestress Concrete Fabricator prior to the start of production. WSDOT certification will be granted at, and renewed during, the annual prestressed plant review and approval process.

Prior to the start of production of girders, the Contractor shall advise the Engineer of the production schedule. The Contractor shall give the Inspector safe and free access to the Work. If the Inspector observes any nonspecification Work or unacceptable quality control practices, the Inspector will advise the plant manager. If the corrective action is not acceptable to the Engineer, the girder(s) will be subject to rejection by the Engineer.

The Contracting Agency intends to perform Quality Assurance Inspection. By its inspection, the Contracting Agency intends only to facilitate the Work and verify the quality of that Work. This inspection shall not relieve the Contractor of any responsibility for identifying and replacing defective material and workmanship.

The various types of girders are:

Prestressed Concrete Girder – Refers to prestressed concrete girders of all types, including prestressed concrete I girders, prestressed concrete wide flange I girders, bulb tee girders, deck bulb tee girders, thin flange deck bulb tee girders, precast prestressed members, spliced prestressed concrete girders, and prestressed concrete tub girders.

Prestressed Concrete I Girder – Refers to a prestressed concrete girder with a flanged I shaped cross section, requiring a cast-in-place concrete deck to support traffic loads. WSDOT standard girders in this category include Series W42G, W50G, W58G, and W74G.

Prestressed Concrete Wide Flange I Girder – Refers to a prestressed concrete girder with an I shaped cross section with wide top and bottom flanges, requiring a cast-in-place concrete deck to support traffic loads. WSDOT standard girders in this category include Series WF42G, WF50G, WF58G, WF74G, WF83G, and WF95G.

Bulb Tee Girder – Refers to a prestressed concrete girder, with a wide top flange requiring a cast-in-place concrete deck to support traffic loads. WSDOT standard girders in this category include Series W32BTG, W38BTG, and W62BTG.

Deck Bulb Tee Girder – Refers to a bulb tee girder with a top flange designed to support traffic loads, and designed to be mechanically connected at the flange edges to adjacent girders at the job site. Except where specific requirements are otherwise specified for these girders, deck bulb tee girders shall conform to all requirements specified for bulb tee girders. WSDOT standard girders in this category include Series W35DG, W41DG, W53DG, and W65DG.

Thin Flange Deck Bulb Tee Girder – Refers to a bulb tee girder with a top flange width equal to the girder spacing and requiring a cast-in-place concrete deck to support traffic loads. Except where specific requirements are otherwise specified for these girders, thin flange deck bulb tee girders shall conform to all requirements specified for bulb tee girders. WSDOT standard girders in this category include Series W32TFG, W38TFG, W50TFG, and W62TFG.

Precast Prestressed Member (PCPS Member) – Refers to a precast prestressed slab, precast prestressed ribbed section, or a deck double tee girder. PCPS members are designed to be mechanically connected at the flange or member edges to adjacent PCPS members at the job site. Except where specific requirements are otherwise specified for these girders, PCPS members shall conform to all requirements specified for deck bulb tee girders.

Spliced Prestressed Concrete Girder – Refers to prestressed concrete girders initially fabricated in segments to be longitudinally spliced together with cast-in-place concrete closures at the job site. Except where specific requirements are otherwise specified for these girders, spliced prestressed concrete girders shall conform to all requirements specified for prestressed concrete girders. Anchorages shall conform to Sections 6-02.3(26)B, 6-02.3(26)C, and 6-02.3(26)D. Ducts shall conform to the Section 6-02.3(26)E requirements for internal embedded installation, and shall be round, unless the Engineer approves use of elliptical shaped ducts. Duct-wedge plate transitions shall conform to Section 6-02.3(26)E. Prestressing reinforcement shall conform to Section 6-02.3(26)F. WSDOT standard girders in this category include Series WF74PTG, WF83PTG, and WF95PTG.

Prestressed Concrete Tub Girder – Refers to prestressed concrete trapezoidal box or bathtub girders including those fabricated in segments to be spliced together with cast-in-place concrete closures at the job site. Except where specific requirements are otherwise specified for these girders, prestressed concrete tub girders shall conform to all requirements specified for prestressed concrete girders and spliced prestressed concrete girders. WSDOT standard girders in this category include Series U**G* or Series UF**G*, where U specifies webs without flanges, UF specifies webs with flanges, ** specifies the girder height in inches, and * specifies the bottom flange width in feet.

6-02.3(25)A Shop Drawings

The Plans show design conditions and details for prestressed girders. Deviations will not be permitted, except as specifically allowed by these Specifications, the shop drawings as approved by the Engineer, and by manufacturing processes approved by the annual plant approval process.

Shop drawings shall show the size and location of all cast-in holes for installation of deck formwork hangers and/or temporary bracing. Holes for formwork hangers shall match approved deck formwork plans designed in accordance with Section 6-02.3(16). There shall be no field-drilled holes in prestressed concrete girders. Post-tensioning ducts in spliced prestressed concrete girders shall be located so their center of gravity is in accordance with the Plans.

The Contractor may alter prestressed concrete girder dimensions from that shown in the Plans provided:

1. The girder has the same or higher load carrying capacity (using the current AASHTO LRFD Design Specifications and WSDOT Bridge Design Manual LRFD) as demonstrated by design calculations submitted to the Engineer for approval in accordance with Section 6-01.9, and accompanying the shop drawing submittal;
2. The Contractor receives the Engineer's approval of the shop drawing and design calculation submittal for the modified girder section prior to beginning fabrication of the girder;

3. The Contractor adjusts Substructures to yield the same top of Roadway elevation shown in the Plans; and
4. The depth of the girder is not increased by more than 2-inches and is not decreased, except that in no case shall an increase in the girder depth reduce the minimum vertical clearance of the bridge and girder over a Traveled Way to less than 16-feet 6-inches, or to less than the minimum vertical clearance specified in the Plans if the Plans already specify a minimum vertical clearance of less than 16-feet 6-inches.

The Contractor shall provide 5 copies of the shop drawings to the Engineer for approval, except as otherwise noted. Shop drawings for spliced prestressed concrete girders shall conform to Section 6-02.3(26)A, and 7 copies of the shop drawings shall be submitted to the Engineer for approval. The shop drawings for spliced prestressed concrete girders shall include all details related to the post-tensioning operations in the field, including details of hardware required, tendon geometry, blockout details, and details of additional or modified steel reinforcing bars required in cast-in-place closures. Approval of shop drawings means only that the Engineer accepts the methods and materials, and nature and scope of the details. Approval shall neither confer upon the Contracting Agency nor relieve the Contractor of responsibility for the accuracy of the shop drawing details and their geometric dimensions, or conformity of the shop drawing details with the Contract.

6-02.3(25)B Casting

Before casting girders, the Contractor shall have possession of an approved set of shop drawings. Side forms shall be steel except that cast-in-place concrete closure forms for spliced prestressed concrete girders, interior forms of prestressed concrete tub girders, and end bulkhead forms of prestressed concrete girders may be wood. Interior voids for precast prestressed slabs with voids shall be formed by either wax soaked cardboard or expanded polystyrene forms. The interior void forms shall be secured in the position as shown in the shop drawings as approved by the Engineer, and shall remain in place.

All concrete mixes to be used shall be pre-approved in the WSDOT plant certification process and must meet the requirements of Section 9-19.1. The temperature of the concrete when placed shall be between 50°F and 90°F.

Slump shall not exceed 4-inches for normal concrete nor 7-inches with the use of a high range water reducing admixture, nor 9-inches when both a high range water reducing admixture is used and the water/cement ratio is less than or equal to 0.35. The high range water reducer shall meet the requirements of Sections 9-23.6 and 9-23.7.

Air-entrainment is not required in the concrete placed into prestressed precast concrete girders, including cast-in-place concrete closures for spliced prestressed concrete girders.

No welds will be permitted on steel within prestressed girders. Once the prestressing steel has been installed, no welds or grounds for welders shall be made on the forms or the steel in the girder, except as specified.

The Contractor may form circular block-outs in the girder top flanges to receive falsework hanger rods. These block-outs shall:

1. Not exceed 1-inch in diameter;
2. Be spaced no more than 72-inches apart longitudinally on the girder;

3. Be located 3-inches or more from the outside edge of the top flange on Series W42G, W50G, W58G, girders, and all prestressed concrete tub girders with webs with flanges, and 6-inches or more for all other prestressed concrete girders with flanges.

The Contractor may form circular block-outs in the girder webs to support brackets for roadway slab falsework. These block-outs shall:

1. Not exceed 1-inch in diameter,
2. Be spaced no more than 72-inches apart longitudinally on the girder, and
3. Be positioned so as to clear the girder reinforcing and prestressing steel.

6-02.3(25)C Prestressing

Each stressing system shall have a pressure gauge or load cell that will measure jacking force. Any gauge shall display pressure accurately and readably with a dial at least 6-inches in diameter or with a digital display. Each jack and its gauge shall be calibrated as a unit and shall be accompanied by a certified calibration chart. The Contractor shall provide 1 copy of this chart to the Engineer. The cylinder extension during calibration shall be in approximately the position it will occupy at final jacking force.

Jacks and gauges shall be recalibrated and recertified:

1. Annually,
2. After any repair or adjustment, and
3. Anytime there are indications that the jack calibration is in error.

The Engineer may use load cells to check jacks, gauges, and calibration charts before and during tensioning.

All load cells shall be calibrated and shall have an indicator that shows prestressing force in the strand. The range of this cell shall be broad enough that the lowest 10-percent of the manufacturer's rated capacity will not be used to measure jacking force.

From manufacture to encasement in concrete, all reinforcement used in girders shall be protected against dirt, oil, grease, damage, rust, and all corrosives. If strands in the stressing bed are exposed before they are encased in concrete, the Contractor shall protect them from contamination or corrosion. The protection method requires the Engineer's approval. If steel has been damaged or if it shows rust or corrosion that cannot be fully removed with a soft cloth, it will be rejected.

Post-tensioning of spliced prestressed concrete girders shall conform to Section 6-02.3(26)G, and the following requirements:

1. Before tensioning, the Contractor shall remove all side forms from the cast-in-place concrete closures. From this point until 48-hours after grouting the tendons, the Contractor shall keep all construction and other live loads off the Superstructure and shall keep the falsework supporting the superstructure in place.
2. No welds or welding grounds shall be attached to metal forms, structural steel, or steel reinforcing bars of the structural member.
3. The Contractor shall not tension the post-tensioning reinforcement until the concrete in the cast-in-place closures reaches the minimum compressive strength specified in the Plans (or 5,000-psi if the concrete strength is not specified in the Plans). This strength shall be measured with concrete cylinders made of the same concrete and cured under the same conditions as the cast-in-place closures.

4. All post-tensioning shall be completed before placing the sidewalks and barriers on the Superstructure.

6-02.3(25)D Curing

During curing, the Contractor shall keep the girder in a saturated curing atmosphere until the girder concrete has reached the required release strength. If the Engineer approves, the Contractor may shorten curing time by heating the outside of impervious forms. Heat may be radiant, convection, conducted steam, or hot air. With steam, the arrangement shall envelop the entire surface with saturated steam. The Engineer will not permit hot air curing until after approving the Contractor's proposed method to envelop and maintain the girder in a saturated atmosphere. Saturated atmosphere means a relative humidity of at least 90-percent. The Contractor shall never allow dry heat to touch the girder surface at any point.

Under heat curing methods, the Contractor shall:

1. Keep all unformed girder surfaces in a saturated atmosphere throughout the curing time;
2. Embed a thermocouple (linked with a thermometer accurate to plus or minus 5°F) 6 to 8-inches from the top or bottom of the girder on its centerline and near its midpoint;
3. Monitor with a recording sensor (accurate to plus or minus 5°F) arranged and calibrated to continuously record, date, and identify concrete temperature throughout the heating cycle;
4. Make this temperature record available for the Engineer to inspect;
5. Heat concrete to no more than 100°F during the first two-hours after placing the concrete, and then increase no more than 25°F per hour to a maximum of 175°F;
6. Cool concrete, after curing is complete, no more than 25°F per hour, to 100°F; and
7. Keep the temperature of the concrete above 60°F until the girder reaches release strength.

The Contractor may strip side forms from prestressed concrete girders once the concrete has reached a minimum compressive strength of 3,000-psi. All damage from stripping is the Contractor's responsibility.

Curing of cast-in-place concrete closures for spliced prestressed concrete girders shall conform to Section 6-02.3(11).

6-02.3(25)E Contractors Control Strength

Concrete strength shall be measured on test cylinders cast from the same concrete as that in the girder. These cylinders shall be cured under time-temperature relationships and conditions that simulate those of the girder. If the forms are heated by steam or hot air, test cylinders will remain in the coolest zone throughout curing. If forms are heated another way, the Contractor shall provide a record of the curing time-temperature relationship for the cylinders for each girder to the Engineer. When 2 or more girders are cast in a continuous line and in a continuous pour, a single set of test cylinders may represent all girders provided the Contractor demonstrates uniformity of casting and curing to the satisfaction of the Engineer.

The Contractor shall mold, cure, and test enough of these cylinders to satisfy Specification requirements for measuring concrete strength. The Contractor may use 4-inch by 8-inch or 6-inch by 12-inch cylinders. If heat is used to shorten curing time, the Contractor shall let cylinders cool for at least ½-hour before testing.

Test cylinders may be cured in a moist room or water tank in accordance with WSDOT FOP for AASHTO T-23 after the girder concrete has obtained the required release strength. If, however, the Contractor intends to ship the girder prior to the standard 28-day strength test, the design strength for shipping shall be determined from cylinders placed with the girder and cured under the same conditions as the girder. These cylinders may be placed in a noninsulated, moisture-proof envelope.

To measure concrete strength in the girder, the Contractor shall randomly select 2 test cylinders and average their compressive strengths. The compressive strength in either cylinder shall not fall more than 5-percent below the specified strength. If these 2 cylinders do not pass the test, 2 other cylinders shall be selected and tested.

If too few cylinders were molded to carry out all required tests on the girder, the Contractor shall remove and test cores from the girder under the surveillance of the Engineer. If the Contractor casts cylinders to represent more than 1 girder, all girders in that line shall be cored and tested.

For precast prestressed members, a test shall consist of 4 cores measuring 3-inches in diameter by 6-inches in height (for slabs) and by the thickness of the web (for ribbed sections). Two cores shall be taken from each side of the member and on each side of the member's span midpoint, at locations approved by the Engineer. The core locations for precast prestressed slabs shall be near mid-depth of the slab, within the middle third of the span length, and shall avoid all prestressing strands and steel reinforcing bars. The core locations for precast prestressed ribbed sections shall be immediately beneath the top flange, within the middle third of the span length, and shall avoid all prestressing strands and steel reinforcing bars.

For prestressed concrete tub girders, a test shall consist of 4 cores measuring 3-inches in diameter by the thickness of the web, taken from each web approximately 3-feet to the left and to the right of the center of the girder span. The cores shall avoid all prestressing strands and steel reinforcing bars.

For all other prestressed concrete girders, a test shall consist of 3 cores measuring 3-inches in diameter by the thickness of the web and shall be removed from just below the top flange; 1 at the midpoint of the girder's length and the other 2 approximately 3-feet to the left and approximately 3-feet to the right.

The cores shall be taken in accordance with AASHTO T 24 and shall be tested in accordance with WSDOT FOP for AASHTO T 22. The Engineer may accept the girder if the average compressive strength of the 4 cores from the precast prestressed member, or prestressed concrete tub girder, or of the 3 cores from any other prestressed concrete girder, is at least 85-percent of the specified compressive strength with no 1 core less than 75-percent of specified compressive strength.

If the girder is cored to determine the release strength, the required patching and curing of the patch shall be done prior to shipment. If there are more than 3 holes or if they are not in a neutral location, the prestress steel shall not be released until the holes are patched and the patch material has attained a minimum compressive strength equal to the required release compressive strength or 4,000-psi, whichever is larger.

The Contractor shall coat cored holes with an epoxy bonding agent and patch the holes using the same type concrete as that in the girder, or a mix approved during the annual plant review and approval. The epoxy bonding agent shall meet the requirements of Section 9-26.1 for Type II, Grade 2 epoxy. The girder shall not be shipped until tests show the patch material has attained a minimum compressive strength of 4,000-psi

6-02.3(25)F Prestress Release

Side and flange forms that restrain deflection shall be removed before release of the prestressing reinforcement.

All harped and straight strands shall be released in a way that will produce the least possible tension in the concrete. This release shall not occur until tests show each girder has reached the minimum compressive strength required by the Plans.

The Contractor may request permission to release the prestressing reinforcement at a minimum concrete compressive strength less than specified in the Plans. This request shall be submitted to the Engineer for approval in accordance with Section 6-01.9 and shall be accompanied with calculations showing the adequacy of the proposed release concrete compressive strength. The release strength shall not be less than 3,500-psi, except that the release strength for spliced prestressed concrete girders shall not be less than 4,000-psi. The calculated release strength shall meet the requirements outlined in the Washington State Department of Transportation Bridge Design Manual for tension and compression at release. The proposed minimum concrete compressive strength at release will be evaluated by the Contracting Agency. Fabrication of girders using the revised release strength shall not begin until the Contracting Agency has provided written approval of the revised release compressive strength. If a reduction of the minimum concrete compressive strength at release is allowed, the Contractor shall bear any added cost that results from the change.

6-02.3(25)G Protection of Exposed Reinforcement

When a girder is removed from its casting bed, all bars and strands projecting from the girder shall be cleaned and painted with a minimum dry film thickness of 1-mil of paint Formula No. A-9-73. During handling and shipping, projecting reinforcement shall be protected from bending or breaking. Just before placing concrete around the painted projecting bars or strands, the Contractor shall remove from them all spattered concrete remaining from girder casting, dirt, oil, and other foreign matter.

Grouting of post-tensioning ducts for spliced prestressed concrete girders shall conform to Section 6-02.3(26)H.

6-02.3(25)H Finishing

The Contractor shall apply a Class 1 finish, as defined in Section 6-02.3(14), to:

1. The exterior surfaces of the outside girders;
2. The bottoms, sides, and tops of the lower flanges on all girders; and

All other girder surfaces shall receive a Class 2 finish.

The interface on I-girders and other girders that contact the cast-in-place deck shall have a finish of dense, screeded concrete without a smooth sheen or laitance on the surface. After vibrating and screeding, and just before the concrete reaches initial set, the Contractor shall texture the interface. This texture shall be applied with a steel brooming tool that etches the surface transversely leaving grooves ⅛-inch to ¼-inch wide, between ⅛-inch and ¼-inch deep, and spaced ¼-inch to ½-inch apart.

On the deck bulb tee girder section and all precast prestressed members, the Contractor shall test the roadway deck surface portion for flatness. This test shall occur after floating but while the concrete remains plastic. Testing shall be done with a 10-foot straightedge parallel to the girder centerline and with a flange width straightedge at right angles to the girder centerline. The Contractor shall fill depressions, cut down high spots, and refinish to correct any deviation of more than ¼-inch within the straightedge length. This section of the Roadway surface shall be finished to meet the requirements for finishing roadway slabs, as defined in Section 6-02.3(10) except that, if approved by the Engineer, a coarse stiff broom may be used to provide the finish in lieu of a metal tined comb.

The Contractor may repair rock pockets and other defects in the girder provided the repair is covered in the annual plant approval package. All other repairs and repair procedures shall be documented and approved by the Engineer prior to acceptance of the girder.

6-02.3(25)I Fabrication Tolerances

The girders shall be fabricated as shown in the shop drawings as approved by the Engineer, and shall meet the dimensional tolerances listed below. Construction tolerances of cast-in-place closures for spliced prestressed concrete girders shall conform to the tolerances specified for spliced prestressed concrete girders. Actual acceptance or rejection will depend on how the Engineer believes a defect outside these tolerances will affect the Structure's strength or appearance:

1. Prestressed Concrete Girder Length (overall): ± ¼-inch per 25-feet of beam length, up to a maximum of ± 1-inch.
2. Precast Prestressed Member Length (overall): ± 1-inch.
3. Width (flanges): + ⅜-inch, - ¼-inch.
4. Width (narrow web section): + ⅜-inch, - ¼-inch.
5. Width (Precast Prestressed Member): ± ¼-inch.
6. Girder Depth (overall): ± ¼-inch.
7. Flange Depth:

For I and Wide Flange I girders:	± ¼-inch
For bulb tee and deck bulb tee girders:	+ ¼-inch, - ⅛-inch
For PCPS members:	+ ¼-inch, - ⅛-inch

8. Strand Position in Prestressed Concrete Girder: ± ¼-inch from the center of gravity of an individual strand; ± ½-inch from the center of gravity of a bundled strand group; ± 1-inch from the center of gravity of the harped strands at the girder ends.
9. Strand Position in Precast Prestressed Member: ± ¼-inch from the center of gravity of a bundled strand group and of an individual strand.
10. Longitudinal Position of the Harping Point:

Single harping point	± 18-inches
Multiple bundled strand groups	
First bundled strand group	± 6-inches
Second bundled strand group	± 18-inches
Third bundled strand group	± 30-inches

11. Position of an interior void, vertically and horizontally (Precast Prestressed Slab with voids): ± ½-inch.
12. Bearing Recess (center recess to beam end): ± ¼-inch.
13. Beam Ends (deviation from square or designated skew):
    Horizontal: ± ½-inch from web centerline to girder flange
    Vertical: ± ⅛-inch per foot of beam depth
14. Precast Prestressed Member Ends (deviation from square or designated skew): ± ½-inch.
15. Bearing Area Deviation from Plane (in length or width of bearing): 1⁄16-inch.
16. Stirrup Reinforcing Spacing: ± 1-inch.
17. Stirrup Projection from Top of Beam: ± ¾-inch.
18. Mild Steel Concrete Cover: - ⅛-inch, + ⅜-inch.
19. Offset at Form Joints (deviation from a straight line extending 5-feet on each side of joint): ± ¼-inch.
20. Deviation from Design Camber (Precast Prestressed Member): ± ¼-inch per 10-feet of member length measured at midspan, but not greater than ± ¾-inch total.
21. Differential Camber Between Girders in a Span (measured in place at the job site):

For I, Wide Flange I, bulb tee, and spliced prestressed concrete girders:	⅛-inch per 10-feet of beam length.
For deck bulb tee girders:	Cambers shall be equlized by an approved method when the differences in cambers between adjacent girders or stages measured at mid-span exceeds ¼-inch.
For PCPS members:	± ¼-inch per 10-feet of member length measured at midspan, but not greater than ± ½-inch total.
For prestressed concrete tub girders:	± ¼-inch per 10-feet of member length measured at midspan, but not greater than ± ½-inch total.

22. Position of Inserts for Structural Connections: ± 1-inch.
23. Position of Lifting Loops: ± 3-inches longitudinal, ± 1-inch transverse.
24. Weld plates for bulb tee girders shall be placed ± ½-inch longitudinal and ± ⅛-inch vertical.
25. Position of post-tensioning ducts at girder and CIP closure ends: ± ¼-inch.
26. Position of post tensioning ducts along segments of segmental prestressed concrete girders: ± ¼-inch.
27. Deviation from a smooth curve for post-tensioning ducts at closures based on the sum total of duct placement and alignment tolerances: ± ⅜-inch.

6-02.3(25)J Horizontal Alignment

The Contractor shall check and record the horizontal alignment of both top and bottom flanges of each girder upon removal of the girder from the casting bed. The Contractor shall also check and record the horizontal alignment within a 2-week period prior to shipment, but no less than 3-days prior to shipment. If the girder remains in storage for a period exceeding 120-days, the Contractor shall check and record the horizontal alignment at approximately 120-days. Each check shall be made by measuring the distance between each flange and a chord that extends the full length of the girder. The Contractor shall perform and record each check at a time when the alignment of the girder is not influenced by temporary differences in surface temperature. These records shall be available for the Engineer's inspection and included in the Contractor's Prestressed Concrete Certificate of Compliance.

Immediately after the girder is removed from the casting bed, neither flange shall be offset more than ⅛-inch for each 10-feet of girder length. During storage and prior to shipping, the offset (with girder ends plumb and upright and with no external force) shall not exceed ¼-inch per 10-feet of girder length. Any girder within this tolerance may be shipped, but must be corrected at the job site to the ⅛-inch maximum offset per 10-feet of girder length before concrete is placed into the diaphragms.

The Engineer may permit the use of external force to correct girder alignment at the plant or job site if the Contractor provides stress calculations and a proposed procedure. If external force is permitted, it shall not be released until after the roadway slab has been placed and cured 10-days.

The maximum deviation of the side of the precast prestressed slab, or the edge of the roadway deck slab of the deck double tee girder or the precast prestressed ribbed section, measured from a chord that extends end to end of the member, shall be ± ⅛-inch per 10-feet of member length, but not greater than ½-inch total.

A final alignment check shall be performed within 3-days prior to shipment to the jobsite. All precast prestressed members which exceed the specified horizontal alignment tolerance may be subject to rejection.

6-02.3(25)K Girder Deflection

The Contractor shall check and record the vertical deflection (camber) of each girder upon removal of the girder from the casting bed. If the girder remains in storage for a period exceeding 120-days, the Contractor shall check and record the vertical deflection (camber) within a 2-week period prior to shipment, but no less than 3-days prior to shipment. The Contractor shall perform and record each check at a time when the alignment of the girder is not influenced by temporary differences in surface temperature. These records shall be available for the Engineer's inspection, and in the case of girders older than 120-days, shall be transmitted to the Engineer as soon as practical for evaluation of the effect of long-term storage on the "D" dimension. These records shall also be included in the Contractor's Prestressed Concrete Certificate of Compliance.

The "D" dimensions shown in the Plans are computed girder deflections at midspan based on a time lapse of 40 and 120-days after release of the prestressing strands, and are intended to advise the Contractor as to the expected range of girder deflection at the time of deck forming. A positive (+) "D" dimension indicates upward deflection.

The Contractor shall control the deflection of prestressed concrete girders that are to receive a cast-in-place slab by scheduling fabrication between 40 and 120-days of slab placement on the erected girders.

If it is anticipated that the girders will be older than 120-days at the time of erection, the Contractor shall submit calculations to the Engineer showing the estimated girder deflection at midspan at the age anticipated for erection. This submittal shall also include the Contractor's proposal for accommodating any excess camber in the construction. The Contractor shall not proceed with girder fabrication until this submittal is approved by the Engineer. The actual girder deflection at the midspan may vary from the maximum estimated "D" dimension at the time of slab forming by a maximum of plus ½-inch for girder lengths up to 80-feet, and plus 1-inch for girder lengths over 80-feet, but less than or equal to 140-feet, and plus 1½-inches for girder lengths over 140-feet.

All costs, including roadway slab form adjustments required to maintain specified steel reinforcing bar clearances and deck profiles, and any additional Contracting Agency engineering expenses, in connection with accommodating excess girder deflection shall be at the Contractor's expense.

6-02.3(25)L Handling and Storage

During handling and storage, each girder shall always be kept plumb and upright, and each precast prestressed member and prestressed concrete tub girder shall always be kept in the horizontal orientation as shown in the Plans. It shall be lifted only by the lifting embedments (strand lift loops or high-strength threaded steel bars) at either end. For strand lift loops, only ½-inch diameter or 0.6-inch diameter strand conforming to Section 9-07.10 shall be used, and a minimum 2-inch diameter straight pin of a shackle shall be used through the loops. Multiple loops shall be held level in the girder during casting in a manner that allows each loop to carry its share of the load during lifting. The minimum distance from the end of the girder to the strand lift loops shall be 1-foot 9-inches. The loops shall project a minimum of 1-foot 6-inches from the top of the girder, and shall extend to within 3-inches clear of the bottom of the girder, terminating with a 9-inch long 90-degree hook. Loads on individual loops shall be limited to 12-kips, and all girders shall be picked up at a minimum angle of 60-degrees from the top of the girder. For high-strength threaded steel bars, a minimum of two 1⅓-inch diameter bars conforming to Section 9-07.11 shall be used at each end of the girder. The lifting hardware that connects to the bars shall be designed, detailed, and furnished by the Contractor. The minimum distance from the end of the girder to the centroid of the lifting bars shall be 3-feet 0-inches. Lifting bars shall extend to within 3-inches clear of the bottom of the girder and shall be anchored in the bottom flange with steel plates and nuts. The minimum size of embedded plates for lifting bars shall be ½-inch thick by 3-inches square. Lifting forces on the lifting bars shall not exceed 58-kips on an individual bar, and shall be within 10-degrees of perpendicular to the top of the girder.

For some girders, straight temporary top flange strands may be specified in the Plans. <u>These temporary strands shall be of the same diameter, and shall be tensioned to the same force, as the permanent strands.</u> Pretensioned top temporary strands for full length prestressed concrete girders shall be unbonded over all but the end 10-feet of the girder length. <u>As an alternative for full length prestressed concrete girders, temporary top strands may be post-tensioned on the same day as the permanent prestressing is released into the girder. The inside diameter of the debonding sleeves shall be large enough such that the temporary strands fully retract upon cutting.</u> When temporary top strands are specified for spliced prestressed concrete girders, the temporary top strands shall be post-tensioned prior to lifting the assembled girder. When the post-tensioned alternative is used, the Contractor shall be responsible for properly sizing the anchorage plates, and the reinforcement adjacent to the anchorage plates, to prevent bursting or splitting of the concrete in the top flange. Temporary strands shall be cut or released in accordance with Section 6-02.3(25)N.

The Contractor may request permission to use lifting embedments, lifting embedment locations, lifting angles, concrete release strengths, or temporary top strand configurations other than specified in the Plans. The number of temporary top strands may be increased from the number shown in the Plans but shall not be decreased. The request, including calculations showing the adequacy of the proposed lifting method, shall be submitted to the Engineer for approval in accordance with Section 6-01.9. The Contractor's analysis shall conform to Article 5.4.1 of the *PCI Design Handbook, Precast and Prestressed Concrete*, Sixth Edition, or other approved methods. The Contractor's analysis shall conform to Article 5.2.9 of the *PCI Design Handbook, Precast and Prestressed Concrete*, Fifth Edition, or other approved methods. The Contractor's calculations shall verify that the concrete stresses in the prestressed girder do not exceed those listed in Section 6-02.3(25)M. The Contractor shall not begin girder lifting operations under the provisions of the lifting method submittal until receiving the Engineer's written approval of the submittal, and shall perform the girder lifting operations at no additional expense to the Contracting Agency.

If girders are to be stored, the Contractor shall place them on a stable foundation that will keep them in a vertical position. Stored girders shall be supported at the bearing recesses or, if there are no recesses, approximately 18-inches from the girder ends. Precast prestressed members shall be supported at points between 1-foot 0-inches and 2-feet 0-inches from the member ends. After post-tensioning, segmental prestressed concrete girders shall be supported at points between 2-feet 0-inches and 5-feet 0-inches from the girder ends, unless otherwise shown in the Plans. For long-term storage of girders with initial horizontal curvature, the Contractor may wedge 1 side of the bottom flange, tilting the girders to control curvature. If the Contractor elects to set girders out of plumb during storage, the Contractor shall have the proposed method analyzed by the Contractor's engineer to ensure against damaging the girder.

6-02.3(25)M Shipping

After the girder has reached its 28-day design strength, and the fabricator believes it to comply with the Specification, the girder and a completed Certification of Compliance, signed by a Precast/Prestressed Concrete Institute Certified Technician or a professional engineer, acceptable to the Contracting Agency, shall be submitted to the Engineer for inspection. If the Engineer finds the certification and the girder to be acceptable, the Engineer will stamp the girder "Approved for Shipment."

No double tee girder, deck double tee girder, precast prestressed slab or precast prestressed ribbed section shall be shipped for at least 3-days after concrete placement. No deck bulb tee girder or prestressed concrete tub girder shall be shipped for at least 7-days after concrete placement, except that deck bulb tee girders or prestressed concrete tub girders may be shipped 3-days after concrete placement when L/(bd) is less than or equal to 5.0, where L equals the shipping length of the girder, b equals the girder top flange width (for deck bulb tee girders) or the bottom flange width (for prestressed concrete tub girders), and d equals the girder depth, all in feet. No other girder shall be shipped for at least 10-days after concrete placement.

Girder support during shipping shall be located as shown in the Plans. These support locations have been determined in accordance with the criteria specified in the WSDOT Bridge Design Manual LRFD Section 5.6.3.D. The Contractor shall verify the applicability of these criteria to the trucking configuration intended for transport of the girders. If the trucking configuration differs from these criteria, the Contractor shall submit a girder shipping plan, with supporting calculations, to the Engineer for approval in accordance with Section 6-01.9.

The Contractor may request permission to use support locations other than those specified. The Contractor shall submit the support location modification proposal, with supporting calculations, to the Engineer for approval in accordance with Section 6-01.9. If the support locations are moved closer to the longitudinal ends of the girders, the calculations shall demonstrate adequate control of bending during shipping. The calculations shall also show that concrete stresses in the girders will not exceed those listed below.

If the Contractor elects to assemble spliced prestressed concrete girders into components of 2 or more segments prior to shipment, the Contractor shall submit shipment support location Working Drawings with supporting calculations to the Engineer in accordance with Section 6-01.9. The calculations shall show that concrete stresses in the assembled girders will not exceed those listed below.

Lateral bracing for shipping is not required for prestressed concrete tub girders and precast prestressed members as defined in Section 6-02.3(25).

For all prestressed concrete girders, except prestressed concrete tub girders and precast prestressed members, the Contractor shall provide bracing to control lateral bending during shipping, unless the Contractor furnishes calculations in accordance with Section 6-01.9 demonstrating that bracing is not necessary. External bracing shall be attached securely to the top flange of the girder. The Contractor is cautioned that more conservation guidelines for lateral bracing may be required for some delivery routes. The Contractor shall submit a bracing plan, with supporting calculations, to the Engineer for approval in accordance with Section 6-01.9. The Contractor shall not begin shipping the girders until receiving the Engineer's approval of the bracing plan, and shall perform all bracing operations at no additional cost to the Contracting Agency.

Criteria for Checking Girder Stresses at the Time of Lifting or Transporting and Erecting. Stresses at both the support and harping points shall be satisfied based on these criteria:

1. Allowable compression stress, fc = 0.60f'cm
    a. f'cm = compressive strength at time of lifting or transporting verified by test but shall not exceed design compressive strength (f'c) at 28-days in psi + 1,000-psi
2. Allowable tension stress, ksi
    a. With no bonded reinforcement = 3 times square root (f'cm) ≤ 0.20 ksi
    b. With bonded reinforcement to resist total tension force in the concrete computed on the basis of an uncracked section = 6.0 times square root (f'cm). The allowable tensile stress in the reinforcement is 30 ksi
3. Prestress losses
    a. for lifting from casting beds = computed losses at 1-day
    b. for transportation = computed losses at 10-days
4. Impact on dead load
    a. Lifting from casting beds = 0-percent
    b. Transporting and erecting = 20-percent

6-02.3(25)N Prestressed Concrete Girder Erection

Before beginning to erect any prestressed concrete girders, the Contractor shall submit to the Engineer for review and shall have received approval for the erection plan and procedure describing the methods the Contractor intends to use. The erection plan and procedure shall provide complete details of the erection process including but not limited to:

1. Temporary falsework support, bracing, guys, deadmen, and attachments to other Structure components or objects;
2. Procedure and sequence of operation;
3. Girder stresses during progressive stages of erection;
4. Girder weights, lift points, lifting embedments and devices, spreaders, and angle of lifting cables in accordance with Section 6-02.3(25)L, etc.;
5. Crane(s) make and model, mass, geometry, lift capacity, outrigger size and reactions;
6. Girder launcher or trolley details and capacity (if intended for use); and
7. Locations of cranes, barges, trucks delivering girders, and the location of cranes and outriggers relative to other Structures, including retaining walls and wing walls.

The erection plan shall include drawings, notes, catalog cuts, and calculations clearly showing the above listed details, assumptions, and dimensions. Material properties and Specifications, structural analysis, and any other data used shall also be included. The plan shall be prepared by (or under the direct supervision of) a Professional Engineer, licensed under Title 18 RCW, State of Washington, in the branch of Civil or Structural, and shall carry the engineer's seal and signature, in accordance with Section 6-02.3(16).

The Contractor shall submit the erection plans, calculations, and procedure directly to the Bridge and Structures Office, Construction Support Engineer, in accordance with Section 6-02.3(16). After the plan is approved and returned to the Contractor, all changes that the Contractor proposes shall be submitted to the Engineer for review and approval.

When prestressed girders arrive on the project, the Project Engineer will confirm that they are stamped "Approved for Shipment" and that they have not been damaged in shipment before accepting them.

The concrete in piers and crossbeams shall reach at least 80-percent of design strength before girders are placed on them. The Contractor shall hoist girders only by the lifting embedments at the ends, always keeping the girders plumb and upright. Once erected, the girders shall be braced to prevent tipping until the intermediate diaphragms are cast and cured. **When temporary strands in the top flange are used, they shall be cut after the girders are braced and before the intermediate diaphragms are cast**. The Contractor shall place the cast-in-place deck on the girders within 30-calendar days of cutting the temporary strands, except as otherwise approved by the Engineer.

For situations where the Contractor proposes to delay placing the cast-in-place deck on the girders beyond 30-calendar days after cutting the temporary strands, the Contractor shall submit supporting girder camber calculations to the Engineer for approval in accordance with Section 6-01.9. The Contractor shall not cut the temporary strands until receiving the Engineer's approval of the girder camber calculations.

Instead of the oak block wedges shown in the Plans, the Contractor may use Douglas fir blocks if the grain is vertical.

The Contractor shall check the horizontal alignment of both the top and bottom flanges of each girder after girder erection but before placing concrete in the bridge diaphragms as described in Section 6-02.3(25)J.

The Contractor shall fill all block-out holes and patch any damaged area caused by the Contractor's operation, with an approved mix, to the satisfaction of the Engineer.

For precast prestressed concrete slabs, the Contractor shall place the 1¼-inch diameter vertical dowel bars at the top of the pier walls as shown in the Plans. The Contractor shall either form the hole or core drill the hole following the alternatives shown in the Plans. The portion of the dowel bar in the top of the pier walls shall be set with either grout that complies with Section 9-26.3 or type II epoxy bonding agent conforming to Section 9-26.1 following placement of each precast prestressed slab.

6-02.3(25)O Deck Bulb Tee Girder Flange Connection

The Contractor shall submit a method of equalizing deck bulb tee girder (and precast prestressed member) deflections to the Engineer for approval in accordance with Section 6-01.9, except that the submittal shall be included with the deck bulb tee girder fabrication shop drawing submittal specified in Section 6-02.3(25)A. Deflection equalizing methods approved for previous Contracting Agency Contracts will be acceptable providing the bridge configuration is similar and the previous method was satisfactory. A listing of the previous Contracting Agency Contract numbers for which the method was used shall be included with the submittal. The weld-ties may be used as a component of the equalizing system provided the Contractor's procedure outlines how the weld-ties are to be used, and that the Contractor's submittal includes a list and description of previous bridge projects where the Contractor has successfully used weld-ties as a component of the equalizing system.

The concrete diaphragms for deck bulb tee girders shall attain a minimum compressive strength of 2,500-psi before any camber equalizing equipment is removed.

On deck bulb tee girders, girder deflection shall be equalized utilizing the approved method before girders are weld-tied and before keyways are filled. Keyways between tee girders shall be filled flush with the surrounding surfaces with nonshrink grout, except that keyways for deck bulb tee girders receiving a cast-in-place concrete deck slab need not be filled with grout. This nonshrink grout shall have a compressive strength of 5,000-psi before the equalizing equipment is removed. Compressive strength shall be determined by fabricating and testing cubes in accordance with WSDOT Test Method 813 and testing in accordance with WSDOT FOP for AASHTO T-106.

Welding ground shall be attached directly to the steel plates being welded when welding the weld-ties on bulb tee girders.

No construction equipment shall be placed on the Structure, other than equalizing equipment, until the girders have been weld-tied and the keyway grout has attained a compressive strength of 5,000-psi.

6-02.3(26) Cast-in-Place Prestressed Concrete

Unless otherwise shown in the Plans, concrete for cast-in-place prestressed bridge members shall be Class 4000D in the roadway deck, and Class 4000 at all other locations. Air entrainment shall conform to Sections 6-02.3(2)A and 6-02.3(3).

The Contractor shall construct supporting falsework in a way that leaves the Superstructure free to contract and lift off the falsework during post-tensioning. Forms that will remain inside box girders to support the roadway slab shall, by design, resist girder contraction as little as possible.

Before tensioning, the Contractor shall remove all side forms from girders. From this point until 48-hours after grouting the tendons, the Contractor shall keep all construction and other live loads off the Superstructure and shall keep the falsework supporting the Superstructure in place.

Once the prestressing steel is installed, no welds or welding grounds shall be attached to metal forms, structural steel, or reinforcing bars of the structural member.

The Contractor shall not stress the strands until all concrete has reached a compressive strength of at least 4,000-psi (or the strength shown in the Plans). This strength shall be measured on concrete test cylinders made of the same concrete cured under the same conditions as the cast-in-place unit.

All post-tensioning shall be completed before sidewalks and barriers are placed.

6-02.3(26)A Shop Drawings

Before casting the structural elements, the Contractor shall submit:

1. Seven sets of shop drawings for approval by the Department of Transportation Bridge and Structures Engineer, Construction Support, addressed as follows:

   If sent via US Postal Service:

   Washington State Department of Transportation
   Bridge and Structures Engineer
   Construction Support
   P. O. Box 47340
   Olympia, WA 98504-7340

   If sent via FedEx:

   Washington State Department of Transportation
   Bridge and Structures Engineer
   Construction Support
   7345 Linderson Way SW
   Tumwater, WA 98501-6504; and

2. Two sets of shop drawings to the Project Engineer.

These shop drawings shall show complete details of the methods, materials, and equipment the Contractor proposes to use in prestressing Work. The shop drawings shall follow the design conditions shown in the Plans unless the Engineer permits equally effective variations.

In addition, the shop drawings shall show:

1. The method and sequence of stressing.
2. Technical data on tendons and steel reinforcement, anchoring devices, anchoring stresses, types of tendon conduit, and all other data on prestressing operations.
3. Stress and elongation calculations. Separate stress and elongation calculations shall be submitted for each tendon if the difference in tendon elongations exceeds 2-percent.
4. That tendons in the bridge will be arranged to locate their center of gravity as the Plans require.
5. Details of additional or modified reinforcing steel required by the stressing system.

6. Procedures and lift-off forces at both ends of the tendon for performing a force verification lift-off in the event of discrepancies between measured and calculated elongations.

Couplings or splices will not be permitted in prestressing strands. Couplings or splices in bar tendons are subject to the Engineer's approval.

Friction losses used to calculate forces of the post-tensioning steel shall be based on the assumed values used for the design. The assumed anchor set, friction coefficient "μ", and friction wobble coefficient "k" values for design are shown in the Plans. The post-tensioning supplier may revise the assumed anchor set value provided all the stress and force limits listed in Section 6-02.3(26)G are met.

The Contractor shall determine all points of interference between the mild steel reinforcement and the paths of the post-tensioning tendons. Details to resolve interferences shall be submitted with the shop drawings for approval. Where reinforcing bar placement conflicts with post-tensioning tendon placement, the tendon profile shown in the Plans shall be maintained. Mild steel reinforcement for post-tensioning anchorage zones shall not be fabricated until after the post-tensioning shop drawings have been approved by the Engineer.

Approval of these shop drawings will mean only that the Engineer considers them to show a reasonable approach in enough detail. Approval will not indicate a check on dimensions.

The Contractor may deviate from the approved shop drawings only after obtaining the Engineer's approval of a written request that describes the proposed changes. Approval of a change in method, material, or equipment shall not relieve the Contractor of any responsibility for completing the Work successfully.

Before physical completion of the project, the Contractor shall provide the Engineer with reproducible originals of the shop drawings (and any approved changes). These shall be clear, suitable for microfilming, and on permanent sheets that measure no smaller than 11 by 17-inches. Alternatively, the shop drawings may be provided in an electronic format with the approval of the Bridge and Structures Engineer.

6-02.3(26)B General Requirements for Anchorages

Post-tensioning reinforcement shall be secured at each end by means of an approved anchorage device, which shall not kink, neck down, or otherwise damage the post-tensioning reinforcement. The anchorage assembly shall be grouted to the Engineer's satisfaction.

The Structure shall be reinforced with steel reinforcing bars in the vicinity of the anchorage device. This reinforcement shall be categorized into 2 zones. The first or local zone shall be the anchorage region that closely surrounds the specific anchorage device. The second or general zone shall be the portion of the anchorage region more remote from the immediate anchorage device.

The steel reinforcing bars required locally for the concrete confinement immediately around the anchorage device (first or local zone) shall be calculated by the post-tensioning system supplier and shall be shown in the shop drawings. The calculations shall be submitted with the shop drawings. The first or local zone steel reinforcing bars shall be furnished and installed by the Contractor, at no additional cost to the Contracting Agency, in addition to the structural reinforcement required by the Plans. The steel reinforcing bars required in the second or general zone shall be as shown in the Plans and are included in the appropriate Bid items.

The Contractor shall submit details, certified test reports, and/or supporting calculations, as specified below, which verify the structural adequacy of the anchorage devices for approval by the Engineer. This requirement does not apply where the anchorage devices have been previously approved by the Contracting Agency for the same Structure configuration. The Contractor shall also submit any necessary changes to the Contract Plans. The test report shall specify all pertinent test data.

Dead ended anchorages will not be permitted. Dead ended anchorages are defined as anchorages that cannot be accessed during the stressing operations.

Materials and workmanship shall conform to the applicable requirements of Sections 6-03 and 9-06.

Before installing the anchorage device, the Contractor shall submit to the Engineer a Manufacturer's Certificate of Compliance in accordance with Section 1-06.3.

The Contractor's proposed anchorage devices shall meet the requirements listed in either Sections 6-02.3(26)C or 6-02.3(26)D.

6-02.3(26)C Bearing Type Anchorages

Bearing type anchorages shall conform to the following requirements:

1. The allowable bearing stress under P_{jack} prior to seating shall be taken:
   a. If ρ_s = 0-percent then $f_{cpi} = 0.5\ f_{ci}\ (A/A_g)^{1/2} < f_{ci}$
   b. If ρ_s 2-percent then $f_{cpi} = 0.75\ f_{ci}\ (A/A_g)^{1/2} < 1.5\ f_{ci}$

   For ρ_s between 0-percent and 2-percent the allowable bearing stress may be linearly interpolated.

   For lightweight concrete the allowable bearing stress shall be reduced by 20-percent.
2. The average concrete bearing stress on the net bearing area at the time of jacking shall not exceed:

   $f_{bi} = P_{jack}/A_{net} < f_{cpi}$
3. The bending stress in bearing plate at P_{jack} shall not exceed:

   $f_s = 3f_{bi}\ (n/t)^2 < 0.8f_{sy}$

   with stiffness $n/t < 0.08\ (E_s/f_{bi})^{1/3}$
4. The allowable bearing stress between bearing plate and wedge plate at P_{jack} shall not exceed:

   $f_{sbi} < 1.5\ f_{sy}$

   where:

P_{jack}	=	Jacking force, but not less than 80-percent MUTS
MUTS	=	Acronym for Minimum Ultimate Tensile Strength, MUTS is the force equal to the nominal cross sectional area of strand, or bar, times their nominal tensile stress
AUTS	=	Acronym for Actual Ultimate Tensile Strength, measured as a force
a_x	=	Dimension of distribution area in X direction
a_y	=	Dimension of distribution area in Y direction
$A = a_x\ a_y$	=	Distribution area within concrete support area
b_x	=	Dimension of bearing plate in X direction

b_y = Dimension of bearing plate in Y direction
A_b = Net bearing area
A_{net} = Net bearing plate area after deducting center hole area
$A_g = b_x\ b_y$ = Gross bearing area
e_{max}, e_{min} = Maximum and minimum edge cover of bearing plate in distribution area
f_{ci} = Compressive strength of concrete at time of initial stressing
f_{cpi} = Permissible concrete compressive strength at time of jacking
f_{bi} = Average uniform concrete bearing stress under bearing plate prior to seating produced by P_{jack}
f_c = Compressive strength of concrete at 28-days
f_s = Bending stress in steel bearing plate
f_{sbi} = Allowable steel bearing stress under P_{jack} between wedge plate and bearing plate
f_{sy} = Yield strength of bearing plate or wedge plate material whichever is lower
n = Largest distance from outer edge of wedge plate to outer edge of bearing plate
ρ_s = Orthogonal reinforcement ratio in each of directions (vertical and horizontal) expressed as a percentage of distribution area
t = Thickness of bearing plate

5. The relationship between gross bearing plate area and distribution area shall satisfy the following conditions in the x and y direction:
   If $e_{min} > 0.5\ b$ then $a = 2b$
   If $e_{min} < 0.5\ b$ then $a = (b + 2\ e_{min})$
   but $e_{max} < 4\ e_{min}$
6. For transverse post-tensioning of roadway slabs, the bearing stress shall not exceed 0.9f'c at P_{jack} of all strands (before seating) or 4,000-psi at service load after all losses.

6-02.3(26)D Non-Bearing Type Anchorages

All anchorages that do not conform to Section 6-02.3(26)C shall be defined as non-bearing type anchorages. Except as allowed by Section 6-02.3(26)B, anchorages and post-tensioning systems with non-bearing type anchorages shall be qualified by test.

Anchorage Qualification Test

A minimum of 3 successful anchorage qualification tests are required for each tendon size. The materials for each qualification test shall be taken from different heats.

Test Block

The test block shall be a square or rectangular prism, depending on the shape of bearing plate. The test block shall conform to the following:

1. The test block width and depth in each direction shall be 3-inches plus the smaller of the following:
   a. Two times the minimum edge distance from the center of the bearing plate to the face of concrete.
   b. The minimum center-to-center spacing of the bearing plate
2. The length of a test block containing a single anchorage and local zone, loaded in a single machine, shall be at least 2 times the larger cross-sectional test block dimension.
3. The length of test block with an anchorage and local zone on either end, loaded by stressing a test tendon, shall be at least 4 times the larger cross-sectional test block dimension.
4. The first or local zone of reinforcement in the test block behind the anchorage for a distance equal to the largest of the 2 cross-sectional dimensions of the anchorage shall simulate the actual first or local zone of reinforcement used in the Structure. For the remaining length of the test block, the reinforcement may be increased as required to prevent failure in that portion.
5. The concrete strength at the time of testing shall not exceed either the minimum strength specified for the system at the time of tensioning, nor 85-percent of the 28-day cylinder strength for normal weight concrete or 70-percent of the 28-day cylinder strength for lightweight concrete.

Test Procedure

The test force shall be applied to the wedge plate, or anchor nut, either in a testing apparatus or through an oversized tendon. The force shall be applied in stages to 40-percent and then to 80-percent of MUTS. At 40-percent MUTS, the force shall be held for 10-minutes to allow inspection for cracks. At 80-percent MUTS, the force shall be held for 1-hour. Thereafter the force shall be increased to at least 120-percent MUTS, and then either to failure or to the limit of testing equipment.

Acceptance Criteria

For forces up to 40-percent MUTS, the width of concrete cracks shall not exceed 0.002-inch.

After holding the force at 80-percent MUTS for 1-hour, the width of concrete cracks shall not exceed 0.01-inch.

The test block shall not fail prior to reaching 120-percent MUTS.

Post-Tensioning System Qualification Test

A minimum of 1 successful system qualification test for each tendon size is required for a representative full size tendon embedded in a concrete test block. The test shall establish that all tendon components, including the spiral, orthogonal, and surface steel reinforcing bars in the local zone, perform as required.

The test block shall conform to the requirements specified above for the anchorage qualification test.

The test procedure shall conform to the requirements specified above for the anchorage qualification test, except as noted. After the test force has been held at 80-percent MUTS for 1-hour, the force shall be increased to at least 95-percent MUTS.

The acceptance criteria shall be as specified above for the anchorage qualification test.

Wedge Plate Qualification Test

Wedge plates shall meet the following requirements. A minimum of 3 successful wedge plate tests, each from a different heat, for each tendon size are required:

1. After loading to 95-percent MUTS for the tendon and subsequent force release, the permanent deflection of the wedge plate's top surface shall not exceed $^1/_{600}$ of clear span. The load test shall be performed with the wedge plate support simulating conditions in the anchorage assembly. The force shall be applied by pulling on a sample tendon using the strand system wedges.
2. The wedge plate shall be tested to static load tests, or to the loading capacity of the testing equipment. The tests shall simulate actual tendon forces applied to the wedges. The failure force shall be at least 120-percent MUTS for the tendon.

6-02.3(26)E Ducts

Ducts shall be round, except that ducts for transverse post-tensioning of bridge deck slabs may be rectangular. Ducts shall conform to the following requirements for internal embedded installation and external exposed installation. Elliptical shaped duct may be used if approved by the Engineer.

Ducts for Internal Embedded Installation

For longitudinal tendons, the Contractor shall encase each tendon in a semi-rigid, galvanized, ferrous metal duct. Semi-rigid ducts shall be corrugated, and their minimum wall thickness shall be either 26 gage for ducts less than or equal to 2⅝-inches in diameter, or 24-gage for ducts greater than 2⅝-inches in diameter. For prestressing steel bars preassembled with their ducts, the minimum duct thickness shall be 31-gage. For transverse tendons, the Contractor shall encase each tendon in a rigid plastic duct. This duct shall maintain the required profile within a placement tolerance of plus or minus ¼-inch for longitudinal tendons and plus or minus ⅛-inch for transverse slab tendons during all phases of the Work. The ducts shall be completely sealed to keep out all mortar.

Each duct shall be located to place the tendon at the center of gravity alignment shown in the Plans. To keep friction losses to a minimum, the Contractor shall install ducts to the exact lines and grades shown in the Plans. Once in place, the ducts shall be tied firmly in position before they are covered with concrete. During concrete placement, the Contractor shall not displace or damage the ducts.

The ends of the ducts shall:

1. Permit free movement of anchorage devices, and
2. Remain covered after installation in the forms to keep out all water or debris.

The Contractor shall install vents at high points and drains at low points of the tendon profile (and at other places if the Plans require). Vents and drains shall be ½-inch minimum diameter standard steel or polyethylene pipe. Vents shall point upward and remain closed until grouting begins. Drains shall point downward and remain open until grouting begins. Ends of steel vents and drains shall be removed 1-inch inside the concrete surface after grouting has been completed; polyethylene vents and drains may be left flush to the surface unless otherwise directed by the Engineer. Conduit vents are not required for transverse post-tensioning ducts in the roadway slab unless specified in the Plans.

Immediately after any concrete placement, the Contractor shall force blasts of oil-free, compressed air through the ducts to break up and remove any mortar inside before it hardens. Before deck concrete is placed, the Contractor shall satisfy the Engineer that ducts are unobstructed and contain nothing that could interfere with tendon installation, tensioning, or grouting. If the tendons are in place, the Contractor shall show that they are free in the duct.

In temperatures below 32°F, ducts shall be kept free from water to avoid damage from freezing.

Strand tendon duct shall have an inside cross-sectional area large enough to accomplish strand installation and grouting. The area of the duct shall be at least 2.5 times the net area of prestressing steel in the duct. The maximum duct diameter shall be 4½-inches.

The inside diameter of bar tendon duct shall at least be ¼-inch larger than the bar diameter. At coupler locations the duct diameter shall at least be ¼-inch larger than the coupler diameter.

Ducts installed and cast into concrete prior to prestressing steel installation, shall be capable of withstanding at least 10-feet of concrete fluid pressure.

Ducts shall have adequate longitudinal bending stiffness for smooth, wobble free placement. A minimum of 3 successful duct qualification tests are required for each diameter and type of duct, as follows:

1. Ducts with diameters 2-inches and smaller shall not deflect more than 3-inches under its own weight, when a 10-foot. duct segment is supported at its ends.
2. Ducts larger than 2-inches in diameter shall not deflect more than 3-inches under its own weight, when a 20-foot duct segment is supported at its ends.
3. Duct shall not dent more than ⅛-inch under a concentrated load of 100-pounds applied between corrugations by a #4 steel reinforcing bar.

When the duct must be bent in a tight radius, more flexible duct may be used, subject to the Engineer's approval.

Ducts for External Exposed Installation

Duct shall be high-density polyethylene (HDPE) conforming to ASTM D 3350. The cell classification for each property listed in Table 1 shall be as follow:

Property	Cell Classification
1	3 or 4
2	2, 3, or 4
3	4 or 5
4	4 or 5
5	2 or 3
6	2, 3, or 4

The color code shall be C.

Duct for external tendons, including their splices, shall be water tight, seamless or welded, and be capable of resisting at least 150-psi grout pressure.

Transition couplers between ducts shall conform to either the standard pressure ratings of ASTM D 3505 or the hydrostatic design stresses of ASTM F 714 at 73°F. The inside diameter through the coupled length shall not be less than that produced by the dimensional tolerances specified in ASTM D 3505.

Workers performing HDPE pipe welding shall have satisfactorily completed a certified HDPE pipe welding course and shall have a minimum of 5-years experience in welding HDPE pipe.

The Contractor shall submit the name and HDPE pipe welding work experience of each HDPE pipe welder proposed to perform this Work in the project. The experience submittal for each HDPE pipe welder shall include:

The Engineer may require the HDPE pipe welder to demonstrate test HDPE pipe welding before receiving final approval.

1. The name of the pipe welder.
2. The name, date, and location of the certified HDPE pipe welding course, with the course completion certificate.
3. A list of at least 3 projects in the last 5-years where the pipe welder performed HDPE pipe welding, including:
    a. The project name and location, and date of construction.
    b. The Governmental Agency/Owner.
    c. The name, address, and phone number of the Governmental Agency/Owner's representative.

The Contractor shall not begin HDPE pipe welding operations until receiving the Engineer's approval of the work experience submittal for each HDPE pipe welder performing HDPE pipe welding in the project.

Transitions

Transitions between ducts and wedge plates shall have adequate length to reduce the angle change effect on the performance of strand-wedge connection, friction loss at the anchorage, and fatigue strength of the post-tensioning reinforcement.

6-02.3(26)F Prestressing Reinforcement

All prestressing reinforcement strand shall comply with Section 9-07.10. They shall not be coupled or spliced. Tendon locations shown in the Plans indicate final positions after stressing (unless the Plans say otherwise). No tendon made of 7-wire strands shall contain more than 37 strands of ½-inch diameter, or more than 27 strands of 0.6-inch diameter.

All prestressing reinforcement bar shall conform to Section 9-07.11. They shall not be coupled or spliced except as otherwise specified in the Plans or Special Provisions.

Prestressing reinforcement not conforming to either Section 9-07.10 or 9-07.11 will not be allowed except as otherwise noted. Such reinforcement may be used provided it is specifically allowed by the Plans or Special Provisions, it satisfies all material and performance criteria specified in the Plans or Special Provisions, and receives the Engineer's approval.

From the time prestressing reinforcement is manufactured until it is grouted or encased in concrete, the Contractor shall protect it from dirt, grease, rust, corrosives, and all physical damage. The Engineer will reject prestressing reinforcement that shows any sign of damage, rust, or corrosion. If the prestressing reinforcement will not be stressed and grouted for more that 10-calendar days after it is placed in the ducts, the Contractor shall place an approved corrosion inhibitor in the ducts.

The feeding ends of the strand tendons shall be equipped with a bullet nosing or similar apparatus to facilitate strand tendon installation.

Strand tendons may be installed by pulling or pushing. Any equipment capable to performing the task may be used, provided it does not damage the strands and conforms to the following:

1. Pulling lines shall have a capacity of at least 2.5 times the dead weight of the tendons when used for essentially horizontal tendon installation.
2. Metal pushing wheels shall not be used.
3. Bullets for checking duct clearance prior to concreting shall be rigid and be ⅛-inch smaller than the inside diameter of the duct. Bullets for checking duct after concreting shall be less than ¼-inch smaller than the inside diameter of the duct.

6-02.3(26)G Tensioning

Equipment for tensioning post-tensioning reinforcement shall meet the following requirements:

1. Stressing equipment shall be capable to produce a jacking force of at least 80-percent MUTS of the post-tensioning reinforcement.
2. Jacking force test capacity shall be at least 95-percent MUTS of the post-tensioning reinforcement.
3. Wedge seating methods shall assure uniform seating of wedge segments and uniform wedge seating losses on all strand tendons.
4. Accumulation of differential seating losses during tensioning cycling shall be prevented by proper devices.
5. Jacks used for stressing tendons less than 20-feet long shall have wedge power seating capability.

The Contractor shall not begin to tension the tendons until:

1. All concrete has reached a compressive strength of at least 4,000-psi or the strength specified in the Plans (demonstrated on test cylinders made of the same concrete cured under the same conditions as that in the bridge), and
2. The Engineer is satisfied that all strands are free in the ducts.

Tendons shall be tensioned to the values shown in the Plans (or approved shop drawings) with hydraulic jacks. When stressing from both ends of a tendon is specified, it need not be simultaneous unless otherwise specified in the Plans. The jacking sequence shall follow the approved shop drawings.

Each jack shall have a pressure gauge that will determine the load applied to the tendon. The gauge shall display pressure accurately and readably with a dial at least 6-inches in diameter or with a digital display. Each jack and its gauge shall be calibrated as a unit and shall be accompanied by a certified calibration chart. The Contractor shall provide 1 copy of this chart to the Engineer for use in monitoring. The cylinder extension during calibration shall be in approximately the position it will occupy at final jacking force.

All jacks and gauges must be recalibrated and recertified: (1) at least every 180-days, and (2) after any repair or adjustment. The Engineer may use pressure cells to check jacks, gauges, and calibration charts before and during tensioning.

These stress limits apply to all tendons (unless the Plans set other limits):

1. Maximum service load after all losses: 80-percent of the specified yield point stress of the steel.
2. Maximum tensile stress during jacking: 80-percent MUTS of the tendon.
3. Maximum initial stress at anchorage after seating: 70-percent MUTS of the tendon.

Tendons shall be anchored at initial stresses that will ultimately maintain service loads at least as great as the Plans require.

As stated in Section 6-02.3(26)A, the assumed design friction coefficient "μ" and wobble coefficient "k" shown in the Plans shall be used to calculate the stressing elongation. These coefficients may be revised by the post-tensioning supplier by the following method provided it is approved by the Engineer:

> Early in the project, the post-tensioning supplier shall test, in place, 2 representative tendons of each size and type shown in the Plans, for the purpose of accurately determining the friction loss in a strand and/or bar tendon.
>
> The test procedure shall consist of stressing the tendon at an anchor assembly with load cells at the dead end and jacking end. The test specimen shall be tensioned to 80-percent of ultimate in 10 increments. For each increment, the gauge pressure, elongation, and load cell force shall be recorded and the data furnished to the Engineer. The theoretical elongations and post-tensioning forces shown on the post-tensioning shop drawings shall be re-evaluated by the post-tensioning supplier using the results of the tests and corrected as necessary. Revisions to the theoretical elongations shall be submitted to the Engineer for evaluation and approval. The apparatus and methods used to perform the tests shall be proposed by the post-tensioning supplier and be subject to the approval of the Engineer.
>
> All costs associated with testing and evaluating test data shall be included in the unit Contract prices for the applicable items of Work involved.

As tensioning proceeds, the Engineer will be recording the applied load, tendon elongation, and anchorage seating values.

Elongation measurements shall be made at each stressing location to verify that the tendon force has been properly achieved. If proper anchor set has been achieved and the measured elongation of each strand tendon is within plus or minus 7-percent of the approved calculated elongation, the stressed tendon represented by the elongation measurements is acceptable to the Contracting Agency.

In the event discrepancies greater than 7-percent exist between the measured and calculated elongations, the jack calibration shall be checked and stressing records reviewed for any evidence of wire or strand breakage. If the jack if properly calibrated and there is no evidence of wire or strand breakage, a force verification lift off shall be performed to verify the force in the tendon. The post-tensioning supplier force verification lift off procedure shall provide access for visual verification of anchor plate lift off. The jacking equipment shall be capable of bridging and lifting off the anchor plate. The tendon is acceptable if the verification lift off force is not less than 99-percent of the approved calculated force nor more than 70-percent of the specified minimum ultimate tensile strength of the prestressing steel or as approved by the Engineer.

Elongation measurements shall be recorded for bar tendons to verify proper tensioning only. Acceptance will be by force verification lift off. The bar tendon is acceptable if the verification lift off force is not less than 95-percent nor more than 105-percent of the approved calculated force or as approved by the Engineer.

When removing the jacks, the Contractor shall relieve stresses gradually before cutting the prestressing reinforcement. The prestressing strands shall be cut a minimum of 1-inch from the face of the anchorage device.

6-02.3(26)H Grouting

After tensioning the tendons, the Contractor shall again blow oil-free, compressed air through each duct. All drains shall then be closed and the vents opened. Grout caps shall be installed at tendon ends prior to grouting. After completely filling the duct with grout, the Contractor shall pump the grout from the low end at a pressure of not more than 250-psig, except for transverse tendons in deck slabs the grout pressure shall not exceed 100-psig. Grout shall be continuously wasted through each vent until no more air or water pockets show. At this point, all vents shall be closed and grouting pressure at the injector held between 100 and 200-psig for at least 10-seconds, except for transverse tendons in deck slabs the grouting pressure shall be held between 50 and 75-psig for at least 10-seconds. The Contractor shall leave all plugs, caps, and valves in place and closed for at least 24-hours after grouting.

Grouting equipment shall:

1. Include a pressure gauge with an upper end readout of between 275 and 325-psig;
2. Screen the grout before it enters the pump with an easily reached screen that has clear openings of no more than 0.125-inches;
3. Be gravity fed from an attached, overhead hopper kept partly full during pumping; and
4. Be able to complete the largest tendon on the project in no more than 20-minutes of continuous grouting.

In addition, the Contractor shall have standby equipment (with a separate power source) available for flushing the grout when the regular equipment cannot maintain a 1-way flow of grout. This standby equipment shall be able to pump at 250-psig.

The grout shall consist of Portland cement, water, and a water reducing admixture and shall be mixed in the following proportions:

Portland Cement Type I or II	1-Sack
Water	4.5-Gallons Maximum
Water Reducing Admixture	Manufacturer's Recommendation
Fly Ash (Optional)	20-pounds Maximum

The water reducing admixture shall be limited to AASHTO M 194 Type A or D and shall not contain ingredients that may corrode steel (that is chlorides, fluorides, sulfates, or nitrates). Fly ash may be used at the option of the Contractor.

The Contractor shall proportion the mix to produce a grout with a flow of 11 to 20-seconds as determined by WSDOT Test Method for ASTM C 939, Flow of Grout for Preplaced Aggregate Concrete (Flow Cone Method).

The grout ejected from the end vent shall have a minimum flow of 11-seconds.

The grout mix shall be injected within 30-minutes after the water is added to the cement. Temperature of the surrounding concrete shall be at least 35°F from the time the grout injecting begins until 2-inch cubes of the grout have a compressive strength of 800-psi. Cubes shall be made in accordance with WSDOT Test Method T 813 and stored in accordance with WSDOT FOP for AASHTO T 23. If ambient conditions are such that the surrounding concrete temperature may fall below 35°F, the Contractor shall provide a heat source and protective covering for the Structure to keep the temperature of the surrounding concrete above 35°F. Grout temperature shall not exceed 90°F during mixing and pumping. If conditions are such that the temperature of the grout mix may exceed 90°F, the Contractor will make necessary provisions, such as cooling the mix water and/or dry ingredients, to ensure that the temperature of the grout mix does not exceed 90°F.

6-02.3(27) Concrete for Precast Units

Precast units shall not be removed from forms until the concrete has attained a minimum compressive strength of 70-percent of the specified design strength as verified by rebound number determined in accordance with WSDOT FOP for ASTM C 805.

Precast units shall not be shipped until the concrete has reached the specified design strength as determined by testing cylinders made from the same concrete as the precast units. The cylinders shall be made, handled, and stored in accordance with WSDOT FOP for AASHTO T 23 and compression tested in accordance with AASHTO Test Method T 22 and AASHTO Test Method T 231.

Self compacting concrete (SCC) may be used for precast concrete barrier covered under Section 6-10 and drainage items covered under Section 9-12. If self compacting concrete has been approved for use the requirements of Section 6-02.3(4)C consistency shall not apply. Self compacting concrete is concrete that is able to flow under its own weight and completely fill the formwork, even in the presence of dense reinforcement, without the need of any vibration, while maintaining homogeneity. When using SCC modified testing procedures for air content and compressive strength will be used. The modification shall be that molds will be filled completely in 1 continuous lift without any rodding, vibration, tamping or other consolidation methods other than lightly taping around the exterior of the mold with a rubber mallet to allow entrapped air bubbles to escape. In addition the fabricators QC testing shall include Slump Flow Test results, which do not indicate segregation. As part of the plants approval for use of SCC the plant fabricator shall cast 1 barrier, or drainage item and have that barrier or drainage item sawed in half for examination by the Contracting Agency to determine that segregation has not occurred.

6-02.3(28) Precast Concrete Panels

The Contractor shall perform quality control inspection. The manufacturing plant for precast concrete units shall be certified by the Precast/Prestressed Concrete Institute's Plant Certification Program for the type of precast member to be produced, or the National Precast Concrete Association's Plant Certification Program or be an International Congress Building Officials or International Code Council Evaluation Services recognized fabricator of structural precast concrete products, and shall be approved by WSDOT as a Certified Precast Concrete Fabricator prior to the start of production. WSDOT Certification will be granted at, and renewed during, the annual precast plant review and approval process. Products that shall conform to this requirement include noise barrier panels, wall panels, floor and roof panels, marine pier deck panels, retaining walls, pier caps, and bridge deck panels. Precast concrete units that are prestressed shall meet all the requirements of Section 6-02.3(25).

The Contracting Agency intends to perform Quality Assurance Inspection. By its inspection, the Contracting Agency intends only to facilitate the Work and verify the quality of that Work. This inspection shall not relieve the Contractor of any responsibility for identifying and replacing defective material and workmanship.

Prior to the start of production of the precast concrete units, the Contractor shall advise the Engineer of the production schedule. The Contractor shall give the Inspector safe and free access to the Work. If the Inspector observes any nonspecification Work or unacceptable quality control practices, the Inspector will advise the plant manager. If the corrective action is not acceptable to the Engineer, the unit(s) will be rejected.

6-02.3(28)A Shop Drawings

Before casting the structural elements, the Contractor shall submit:

1. Seven sets of shop drawings for approval by the Department of Transportation Bridge and Structures Engineer, Construction Support, addressed as follows:

   If sent via US Postal Service:

   Washington State Department of Transportation
   Bridge and Structures Engineer
   Construction Support
   P. O. Box 47340
   Olympia, WA 98504-7340

   If sent via FedEx:

   Washington State Department of Transportation
   Bridge and Structures Engineer
   Construction Support
   7345 Linderson Way SW
   Tumwater, WA 98501-6504; and

2. Two sets of shop drawings to the Project Engineer.

These shop drawings shall show complete details of the methods, materials, and equipment the Contractor proposes to use in prestressing/precasting Work. The shop drawings shall follow the design conditions shown in the Plans unless the Engineer approves equally effective variations.

The shop drawings shall contain as a minimum:

1. Unit shapes (elevations and sections) and dimensions.
2. Finishes and method of constructing the finish (i.e., forming, rolling, etc.).
3. Reinforcing, joint, and connection details.
4. Lifting, bracing, and erection inserts.
5. Locations and details of hardware attached to the Structure.
6. Relationship to adjacent material.

Approval of these shop drawings shall not relieve the Contractor of responsibility for accuracy of the drawings or conformity with the Contract. Approval will not indicate a check on dimensions.

The Contractor may deviate from the approved shop drawings only after obtaining the Engineer's approval of a written request that describes the proposed changes. Approval of a change in method, material, or equipment shall not relieve the Contractor of any responsibility for completing the Work successfully.

Before completion of the Contract, the Contractor shall provide the Engineer with reproducible originals of the shop drawings (and any approved changes). These shall be clear, suitable for microfilming, and on permanent sheets that conform with the size requirements of Section 6-01.9.

6-02.3(28)B Casting

Before casting precast concrete units, the Contractor and Fabrication Inspector shall have possession of an approved set of shop drawings.

Concrete shall meet requirements of Section 6-02.3(25)B for annual pre-approval of the concrete mix design, and slump.

Precast units shall not be removed from forms until the concrete has attained a minimum compressive strength of 70-percent of the specified design strength. A minimum compressive strength at other than 70-percent may be used for specific precast units if the fabricator requests and receives approval as part of the WSDOT plant certification process.

Forms may be steel or plywood faced, providing they impart the required finish to the concrete.

6-02.3(28)C Curing

Concrete in the precast units shall be cured by either moist or accelerated curing methods. The methods to be used shall be preapproved in the WSDOT plant certification process.

1. For moist curing, the surface of the concrete shall be kept covered or moist until such time as the compressive strength of the concrete reaches the strength specified for stripping. Exposed surfaces shall be kept continually moist by fogging, spraying, or covering with moist burlap or cotton mats. Moist curing shall commence as soon as possible following completion of surface finishing.
2. For accelerated curing, heat shall be applied at a controlled rate following the initial set of concrete in combination with an effective method of supplying or retaining moisture. Moisture may be applied by a cover of moist burlap, cotton matting, or other effective means. Moisture may be retained by covering the unit with an impermeable sheet.

Heat may be radiant, convection, conducted steam or hot air. Heat the concrete to no more than 100°F during the first 2-hours after pouring the concrete, and then increase no more than 25°F per hour to a maximum of 175°F. After curing is complete, cool the concrete no more than 25°F per hour to 100°F. Maintain the concrete temperature above 60°F until the unit reaches stripping strength.

Concrete temperature shall be monitored by means of a thermocouple embedded in the concrete (linked with a thermometer accurate to plus or minus 5°F). The recording sensor (accurate to plus or minus 5°F) shall be arranged and calibrated to continuously record, date, and identify concrete temperature throughout the heating cycle. This temperature record shall be made available to the Engineer for inspection and become a part of the documentation required.

The Contractor shall never allow dry heat to directly touch exposed unit surfaces at any point.

6-02.3(28)D Contractors Control Strength

The concrete strength at stripping and the verification of design strength shall be determined by testing cylinders made from the same concrete as the precast units. The cylinders shall be made, handled, and stored in accordance with WSDOT FOP for AASHTO T 23 and compression tested in accordance with AASHTO Test Method T 22 and AASHTO Test Method T 231.

For accelerated cured units, concrete strength shall be measured on test cylinders cast from the same concrete as that in the unit. These cylinders shall be cured under time-temperature relationships and conditions that simulate those of the unit. If the forms are heated by steam or hot air, test cylinders will remain in the coolest zone throughout curing. If forms are heated another way, the Contractor shall provide a record of the curing time-temperature relationship for the cylinders for each unit to the Engineer. When 2 or more units are cast in a continuous line and in a continuous pour, a single set of test cylinders may represent all units provided the Contractor demonstrates uniformity of casting and curing to the satisfaction of the Engineer.

The Contractor shall mold, cure, and test enough of these cylinders to satisfy Specification requirements for measuring concrete strength. The Contractor may use 4-inch by 8-inch or 6-inch by 12-inch cylinders. The Contractor shall let cylinders cool for at least ½-hour before testing for release strength.

Test cylinders may be cured in a moist room or water tank in accordance with WSDOT FOP for AASHTO T-23 after the unit concrete has obtained the required release strength. If, however, the Contractor intends to ship the unit prior to standard 28-day strength test, the design strength for shipping shall be determined from cylinders placed with the unit and cured under the same conditions as the unit. These cylinders may be placed in a noninsulated, moisture-proof envelope.

To measure concrete strength in the precast unit, the Contractor shall randomly select 2 test cylinders and average their compressive strengths. The compressive strength in either cylinder shall not fall more than 5-percent below the specified strength. If these 2 cylinders do not pass the test, 2 other cylinders shall be selected and tested.

6-02.3(28)E Finishing

The Contractor shall provide a finish on all relevant concrete surfaces as defined in Section 6-02.3(14), unless the Plans or Special Provisions require otherwise.

6-02.3(28)F Tolerances

The units shall be fabricated as shown in the Plans, and shall meet the dimensional tolerances listed in the latest edition of PCI-MNL-166, unless otherwise required by the Plans or Special Provisions.

6-02.3(28)G Handling and Storage

The Contractor shall lift all units only by adequate devices at locations designated on the shop drawings. When these devices and locations are not shown in the Plans, Section 6-02.3(25)L shall apply.

Precast units shall be stored off the ground on foundations suitable to prevent differential settlement or twisting of the units. Stacked units shall be separated and supported by dunnage of uniform thickness capable of supporting the units. Dunnage shall be arranged in vertical planes. The upper units of a stacked tier shall not be used as storage areas for shorter units unless substantiated by engineering analysis and approved by the Engineer.

6-02.3(28)H Shipping

Precast units shall not be shipped until the concrete has reached the specified design strength, and the Engineer has reviewed the fabrication documentation for Contract compliance and stamped the precast concrete units "Approved for Shipment". The units shall be supported in such a manner that they will not be damaged by anticipated impact on their dead load. Sufficient padding material shall be provided between tie chains and cables to prevent chipping or spalling of the concrete.

6-02.3(28)I Erection

When the precast units arrive on the project, the Project Engineer will confirm that they are stamped "Approved for Shipment." The Project Engineer will evaluate the present units for damage before accepting them.

The Contractor shall lift all units by suitable devices at locations designated on the shop drawings. Temporary shoring or bracing shall be provided, if necessary. Units shall be properly aligned and leveled as required by the Plans. Variations between adjacent units shall be leveled out by a method approved by the Engineer.

6-02.4 Measurement

Except as noted below, all classes of concrete shall be measured in place by the cubic yard to the neat lines of the Structure as shown in the Plans.

Exception: concrete in cofferdam seals. Payment for Class 4000W concrete used in these seals will be based on the volume calculated using the neatline dimensions for the seal as shown in the Contract Plans. For calculated purposes, the horizontal dimension will be increased by 1-foot outside the seal neatline perimeter. The vertical dimension is the distance between the top and bottom neatline elevations. No payment will be made for any concrete that lies outside of these limits to accommodate the Contractor's cofferdam configuration. If the Engineer eliminates the seal in its entirety a Contract change order will be issued.

Exception: concrete in a separate lump-sum, Superstructure Bid item. Any concrete quantities noted under this item in the Special Provisions will not be measured. Although the Special Provisions list approximate quantities for the Contractor's convenience, the Contracting Agency does not guarantee the accuracy of these estimates. Before submitting a Bid, the Contractor shall have verified the quantities. Even though actual quantities used may vary from those listed in the Special Provisions, the Contracting Agency will not adjust the lump sum Contract price for Superstructure (except for approved changes).

The Contracting Agency will pay for no concrete placed below the established elevation of the bottom of any footing or seal.

Lean concrete will be measured by the cubic yard for the quantity of material placed per the producer's invoice, except that lean concrete included in other Contract items will not be measured.

No deduction will be made for pile heads, reinforcing steel, structural steel, bolts, weep holes, rustications, chamfers, edgers, joint filler, junction boxes, miscellaneous hardware, ducts or less than 6-inch diameter drain pipes when computing concrete quantities for payment.

All reinforcing steel will be measured by the computed weight of all metal actually in place and required by the Plans or the Engineer. Epoxy-coated bars will be measured before coating. The Contractor shall furnish (without extra allowance):

1. Spreaders, form blocks, wire clips, and other fasteners.
2. Extra steel in splices not shown in the Plans.
3. Extra shear steel at construction joints not shown in the Plans when the Engineer permits such joints for the Contractor's convenience.

The following table shall be used to compute weight of reinforcing steel:

Steel Reinforcing Bar

Deformed Bar Designation Number	Nominal Diameter Inches	Unit Weight Pounds per Foot
3	0.375	0.376
4	0.500	0.668
5	0.625	1.043
6	0.750	1.502
7	0.875	2.044
8	1.000	2.670
9	1.128	3.400
10	1.270	4.303
11	1.410	5.313
14	1.690	7.650
18	2.260	13.600

Gravel backfill will be measured as specified in Section 2-09.4.

No specific unit of measure will apply to the lump sum item for cure box.

Bridge approach slab will be measured by the square yard.

6-02.5 Payment

Payment will be made in accordance with Section 1-04.1, for each of the following Bid items that are included in the Proposal:

"Conc. Class ____", per cubic yard.

"Commercial Concrete", per cubic yard.

All concrete, except in Superstructure when this is covered by a separate Bid item, will be paid for at the unit Contract price per cubic yard in place for the various classes of concrete.

"Superstructure (name bridge)", lump sum.

All costs in connection with providing holes for vents, for furnishing and installing cell drainage pipes for box girder Structures, and furnishing and placing grout and shims under steel shoes shall be included in the unit Contract prices for the various Bid items involved.

All costs in connection with the construction of weep holes, including the gravel backfill for drains surrounding the weep holes except as provided in Section 2-09.4, shall be included by the Contractor in the unit Contract price per cubic yard for "Conc. Class ____".

"Lean Concrete", per cubic yard.

Lean concrete, except when included in another Bid item, will be paid for at the unit Contract price per cubic yard.

"St. Reinf. Bar", per pound.

"Epoxy-Coated St. Reinf. Bar", per pound.

Payment for reinforcing steel shall include the cost of furnishing, fabricating, and placing the reinforcement. In Structures of reinforced concrete where there are no structural steel Bid items, such minor metal parts as expansion joints, bearing assemblies, and bolts will be paid for at the unit Contract price for "Reinforcing Bar" unless otherwise specified.

"Gravel Backfill for Foundation Class A", per cubic yard.

"Gravel Backfill for Foundation Class B", per cubic yard.

"Gravel Backfill for Wall", per cubic yard.

"Deficient Strength Conc. Price Adjustment", by calculation.

"Deficient Strength Conc. Price Adjustment" will be calculated and paid for as described in Section 6-02.3(5)L. For the purpose of providing a common Proposal for all Bidders, the Contracting Agency has entered an amount for the item "Deficient Strength Conc. Price Adjustment" in the Bid Proposal to become a part of the total Bid by the Contractor. The item "Deficient Strength Conc. Price Adjustment" covers all applicable classes of concrete.

"Cure Box", lump sum.

The lump sum Contract price for "Cure Box" shall be full pay for all costs for providing, operating, maintaining, moving and removing the cure boxes and providing, maintaining and operating all necessary power sources and connections needed to operate the curing boxes.

"Bridge Approach Slab", per square yard.

The unit Contract price per square yard for "Bridge Approach Slab" shall be full pay for providing, placing, and compacting the crushed surfacing base course, furnishing and placing Class 4000A concrete, and furnishing and installing compression seal, anchors, and reinforcing steel.